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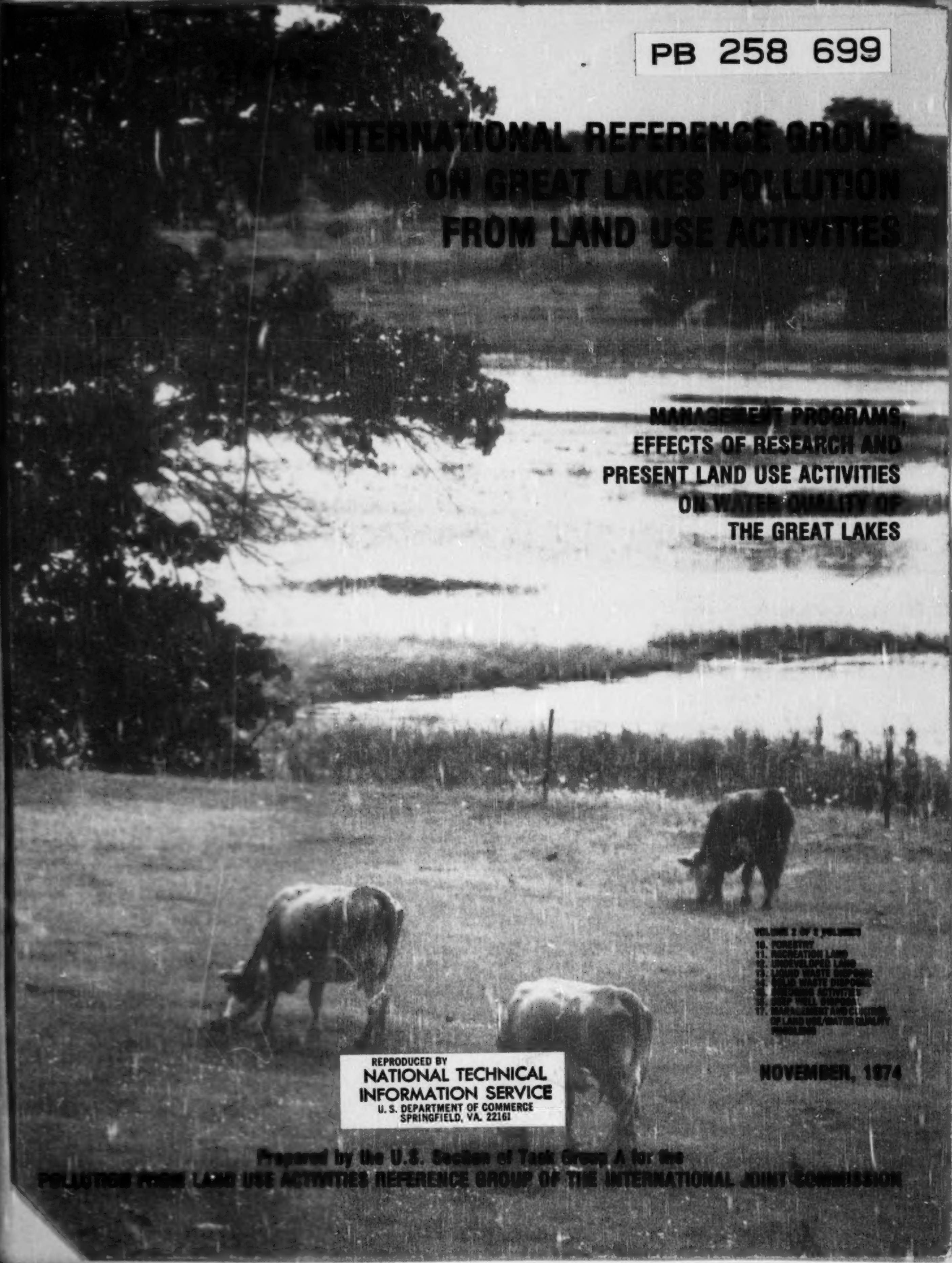

INTERNATIONAL REFERENCE GROUP ON GREAT LAKES POLLUTION FROM LAND USE ACTIVITIES

MANAGEMENT PROGRAMS, EFFECTS OF RESEARCH AND PRESENT LAND USE ACTIVITIES ON WATER QUALITY OF THE GREAT LAKES

VOLUME 2 OF 2 VOLUMES

10. FORESTRY
11. RECREATION LAND
12. UNDEVELOPED LAND
13. LIQUID WASTE DISPOSAL
14. SOLID WASTE DISPOSAL
15. DREDGING ACTIVITIES
16. DEEP WELL DISPOSAL
17. MANAGEMENT AND CONTROL OF LAND USE/WATER QUALITY PROBLEMS

NOVEMBER, 1974

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PREFACE

The Great Lakes Water Quality Agreement, with Annexes and Texts and Terms of Reference Between the United States of America and Canada, signed at Ottawa on April 15, 1972, included a reference to study pollution in the Great Lakes System from agricultural, forestry, and other land use activities. The reference asked that the study assess whether the boundary waters of the Great Lakes System were being polluted by land drainage and if so, what remedial measures would provide improvements in controlling pollutants from land usage. The need for better definition of the impact of land use activities, practices, and programs on water quality in the Great Lakes area had become increasingly magnified. Through the Agreement, both the United States and Canadian governments requested the International Joint Commission to investigate land use activity impacts upon the Great Lakes. Accordingly, the International Reference Group on Great Lakes Pollution From Land Use Activities was established in February, 1973, and produced a detailed study plan (February, 1974) outlining an intensive study, scheduled for completion by 1977.

Detailed Study Plan, February, 1974

The study plan emphasizes four main tasks:

Task A: To assess problems, management of programs and research and to attempt to set priorities in relation to the best information now available on the effects of land use activities on water quality in boundary waters of the Great Lakes.

Task B: Inventory of land use and land use practices, with emphasis on certain trends and projections to 1980 and, if possible, to 2020.

Task C: Intensive studies of a small number of representative watersheds, selected and conducted to permit some extrapolation of data to the entire Great Lakes basin and to relate contamination to water quality, which may be found at river mouths on the Great Lakes, to specific land uses and practices.

Task D: Diagnosis of degree of impairment of water quality in the Great Lakes, including assessment of concentrations of contaminants of concern in sediment, fish and other aquatic resources.

U. S. Task A Study Plan

In order that subsequent tasks may derive full benefit of past and present programs and activities pertinent to the goals of the Reference Group, it was felt to be essential to assess the current state-of-the art or knowledge about land drainage and to inform the Reference Group of current developments. The objectives of Task A were to analyze the pollution problem and potential of various land uses and to document the practicality of alternative, remedial, or control measures.

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In order to meet these objectives for the U. S. portion, studies were agreed upon by Task A members to provide a state-of-the-art assessment for the following categories:

A1: Residential areas
A2: Commercial and industrial areas
A3: Transportation
A4: Extractive areas
A5: Pesticides and herbicides
A6: Nutrients
A7: Erosion and sedimentation
A8: Animal wastes
A9: Intensive animal feedlots
A10: Forestry
A11: Recreation land
A12: Undeveloped land
A13: Liquid waste disposal
A14: Solid waste disposal
A15: Land Fills (dredging activities)
A16: Deepwell disposal
A17: Management and control of land use/water quality problems

Selection of Principal Investigators

Limited amount of funding available from the U. S. Environmental Protection Agency, lead agency for the U. S. Task A effort, required some support from other Federal agencies. The U. S. Department of Agriculture cooperated by having the Soil Conservation Service support Category A7 - Erosion and Sedimentation, and the Forest Service Category A 10 - Forestry. For the other categories, the GLBC staff developed a listing of consulting firms, Universities, and individuals knowledgeable and interested in the various study areas. Requests for proposals at a limited fixed-price were initiated and invitations sent out to all competent to deliver the professional services. After submittal of proposals and professional capabilities, the Task A Group selected the potential principal investigators and associates. The Great Lakes Basin Commission, under contract with the U. S. Environmental Protection Agency, negotiated subcontracts with the organizations and principal investigators. The last category, A17 - Management and control of land use/water quality problems with focus on the Great Lakes States programs, was developed by the Great Lakes Basin Commission staff.

U. S. Task A Study Participants

The lead agency for Task A on the U. S. portion has been the U. S. Environmental Protection Agency with the participation of the Great Lakes Basin Commission, and the U. S. Department of Agriculture's Soil Conservation Service and Forest Service. The Great Lakes Basin Commission acted as the main contractor for fifteen of the categories, while the Department of Agriculture contributed two categories to the U. S. effort.

U.S. members of the Land Use Activities Reference Task A Group included:

Dr. Richard R. Parizek, Pennsylvania State University
Mr. James P. Dooley, Michigan Department of Natural Resources
Mr. John Pegors, Minnesota Pollution Control Agency
Mr. Eugene A. Jarecki, GLBC Technical Representative
Mr. Fred O. Sullivan, U.S. EPA Project Officer

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Task A5: Dr. Gordon Chesters, University of Wisconsin, Madison, Wisconsin
Task A6: Dr. D.E. Armstrong, University of Wisconsin, Madison, Wisconsin
Task A7: Mr. William Mildner, USDA, Soil Conservation Service, Hyattsville, Maryland
Task A8-A9: Dr. Raymond C. Loehr, Cornell University, Ithaca New York
Task A10: Mr. Robert Lindahl, USDA, Forest Service, St. Paul, Minnesota
Task A11: Dr. John Harkin, University of Wisconsin, Madison, Wisconsin
Task A12: Dr. Charles E. Herdenorf, Ohio State University, Columbus, Ohio
Task A13: Dr. Robert H. Miller, Ohio State University, Columbus, Ohio
Task A14: Dr. Charles A. Moore, Ohio State University, Columbus, Ohio
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Task A16: Dr. Wayne A. Pettyjohn, Ohio State University, Columbus, Ohio
Task A17: Mr. Robert W. Reed, Great Lakes Basin Commission, Ann Arbor, Michigan

Assistance in development and review of various phases of Task A is acknowledged by Mr. Merle Tellekson, Mr. Gene Pinkstaff, and Mr. John McGuire from the U.S. Environmental Protection Agency, Region V, Mr. Gerald B. Welsh, USDA-Soil Conservation Service, and Mr. Robert W. Reed of the Great Lakes Basin Commission staff. The Canadians who were particularly helpful include Mr. Kim Shikaze, Environment Canada, Ottawa, and Mr. Martin G. Wood from the Ontario Ministry of the Environment, Toronto. Considerable assistance was also provided by Mr. Pat Chamut of the International Joint Commission Regional Office in Windsor, Ontario.

Each report has been reviewed by the Task A Group and its comments considered before approval for final report development and submittal to the U.S. Environmental Protection Agency for meeting contractual terms. Some reports were reviewed by the International Reference Group on Great Lakes Pollution From Land Use Activities. These reports form the U. S. contribution to the Task A effort. The findings and conclusions of each report reflect the principal investigators' findings and do not necessarily reflect the opinions or positions of their respective agencies, those of the Reference Group, or those of the U.S. Environmental Protection Agency.

NOTE: A joint summary report of the Canadian and United States Task A efforts presenting the findings is being prepared.

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Land Use/Water Quality Relationships in the U.S. Great Lakes Basin
Task A: To assess problems, management of programs and research...

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Land Use/Water Quality Relationships in the U. S. Great Lakes Basin
Task A: To assess problems, management of programs and research...
Category A10 - Forestry

THE EFFECTS OF FORESTRY ACTIVITIES ON THE WATER QUALITY OF THE GREAT LAKES

prepared by
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June 10, 1974

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Section 1

Summary

1.1 Introduction

The United States portion of the Great Lakes drainage area is approximately 304.0 thousand square kilometers (117.6 thousand square miles). Forty-seven percent of the Basin is forested. These forest lands contribute approximately 680 to 940 thousand metric tons (750 to 1040 thousand tons) of sediment, less than 9.2 thousand metric tons (10.2 thousand tons) of nitrogen, 97 metric tons (107 tons) of phosphorus, and undetectable quantities of pesticide residues annually to the Great Lakes. Based on all the literature surveyed, it appears that forest lands contribute a relatively small portion of the total pollutants delivered to the Great Lakes, probably less than 10 percent in most cases. However, there may be significant local concentrations of these pollutants that result in the deterioration of upland surface waters.

Accelerated release of pollutants to upland surface waters can result from such activities as timber harvesting, fires, woodland grazing, insect and disease control, and urbanization.

Pollutants evaluated in this report are sediments, nutrients (phosphorous and nitrogen), herbicides, insecticides and organic matter. The most widespread forest disturbances are timber harvesting, recreation and woodland grazing. The most localized and damaging activity is forest land urbanization. Although these activities occur continually throughout the Basin, the vast majority of forest lands remain in a relatively undisturbed condition. Therefore, the average intensity of forest activities is extremely low.

1.2 Findings and Conclusions

1.2.1 Sediment

Forest lands contribute only 680 to 940 thousand metric tons (750 to 1040 thousand tons) of sediment annually to the Great Lakes. This accounts for both normal (geologic) and accelerated forest land sediment production. Normal or geologic sedimentation accounts for approximately 60 percent of the total forest land sediment yield. The remaining 40 percent originates from only 5 percent of the area. This shows the potential for local damages and the need for controls. These estimates are high, and represent the potential for full utilization with little or no erosion control (45).

Approximately 243 thousand hectares (600 thousand acres) of forest land will be harvested annually to the year 2020. Logging roads and skid trails will cover approximately 10 to 15 percent of these areas. If no management controls are implemented, an estimated 136 thousand metric tons (150 thousand tons) per year of sediment will be delivered to the Great Lakes from these lands. Proper management and control measures could reduce these sediment inputs to negligible levels (44) (45).

Accelerated sediment production will occur on approximately 344 thousand hectares (850 thousand acres) of grazed forest lands annually to the year 2020. These lands will contribute approximately 54 thousand metric tons (60 thousand tons) of sediment annually to the Great Lakes (44) (45).

Forest land urbanization will occur at a rate of 8.3 thousand hectares (20.5 thousand acres) each year to the year 2020 (44). If these lands are intensively developed, the predicted annual sediment delivery will be approximately 273 to 408 thousand metric tons (300 to 450 thousand tons) (45). If cluster developments were constructed in forest lands, thus leaving 40 percent of these lands in a relatively undisturbed condition, annual sediment yield would amount to 136 to 273 thousand metric tons (150 to 300 thousand tons). After construction, extensive areas of impervious surfaces and vegetation will reduce sediment contributions to far less than 136 thousand metric tons (150 thousand tons).

Forest fires burn roughly 7.3 thousand hectares (18.0 thousand acres) annually. Accelerated sediment production from these lands account for less than 14 thousand metric tons (15 thousand tons) annually.

Intensive tree culture, if implemented in the future, will probably be located on nearly level forest and abandoned agricultural lands. This will be to facilitate mechanical silvicultural and harvesting operations. Accelerated erosion and sedimentation are expected to be minor problems.

1.2.2 Nutrients and Organic Matter

An attempt to quantify the nutrient release resulting from forest activities such as harvesting, site preparation, burning or grazing from forest lands in the Great Lakes Basin is extremely difficult at this time. A literature review shows a wide range of nutrient releases from different areas and types of treatment, making data extrapolation difficult. Research in some areas of concern, especially organic and nutrient losses via erosion, is very limited or nonexistent.

Although the water quality effects of forest nutrients and organic matter are difficult to quantify, it is generally conceded that activities such as harvesting, burning and other periodic disturbances have only minor effects. It is also apparent that the effect is highly variable.

No published information is available to evaluate nutrient losses from grazed forest lands. Estimates of the annual nitrogen and phosphorous contributions from these lands are 920 and 32 metric tons (1020 and 36 tons) respectively. Harvested areas are estimated to contribute less than 460 and 32 metric tons (510 and 36 tons) of nitrogen and phosphorous respectively to the Great Lakes each year (46). These quantities seem insignificant in relation to the water quality of the Great Lakes, there may be considerable concern for surface water pollution immediately adjacent to disturbed forest sites.

1.2.3 Pesticides

The impacts of forest applied pesticides on the water quality of the Great Lakes is now and will be minor or undetectable. The small percentages of forest lands sprayed in the past, the present applications of smaller dosages, and the use of less toxic and less persistent chemicals minimize the potential for water quality impairment. Furthermore, the proper application of pesticides and further reductions of erosion and sedimentation in the future should essentially eliminate this potential.

1.3 Recommendations

Research is necessary to adequately quantify the effects of forest lands and forestry activities on the water quality of the Great Lakes Basin. Studies to determine the release of sediment and nutrients after harvesting, burning, grazing, site preparation, fertilization and road building are needed. Until this information is gained, only very rough estimates can be made.

If the intensive tree culture concept is used to maximize fiber production in the aspen type, potentially 30 percent of the total forest lands could be affected. Intensive tree culture involves more intensive cultural activities such as cultivation, drainage, fertilization and a greater frequency of disturbance. Consequently, more intensive management and control techniques will be necessary to minimize adverse impacts on water quality. These potential problems should be thoroughly investigated before intensive tree culture is implemented on a large scale.

Monitoring of pesticide residues in the past has been primarily in the terrestial environment and surface waters. Recent research has shown that sediment may be a principal carrier of pesticide residues. Monitoring should be expanded to sample aquatic sediments.

Section 2

SUPPORTING MATERIAL

2.1 Introduction

Forest disturbances such as harvesting, grazing, burning and urbanization have occurred in the Great Lakes since the early 1800's. Other cultural activities such as recreation and pest management have become significant since 1930. Intensive tree culture may become significant by the year 1990. These activities can accelerate the release of mineral and organic sediments, nutrients and pesticide residues to surface and ground waters. The effects of forest activities on water quality in the Great Lakes Basin are poorly documented. This study attempts to evaluate the present and future impacts of forest activities on the water quality of the Great Lakes.

2.2 Scope of Study

Data were obtained from published papers, reports, texts, symposium proceedings, abstracts and personal interviews. Time references were 1920 to the present for erosion and sediment data; 1934 to the present for insecticide data; 1950 to the present for nutrient and herbicide data; and 1965 to the present for intensive tree culture data. The majority of the literature surveyed was published after 1969 with the greatest number published in 1972. Almost all the literature pertained to investigations outside the Basin.

2.3 Study Procedure

In response to a request made by the Great Lakes Basin Commission, the Forest Service-USDA assembled a five member work group to assess present and future impacts of forest land activities on the water quality of the Great Lakes. The work group consisted of members from Research, National Forest Administration and State & Private Forestry. The group was coordinated by a representative of State & Private Forestry and followed guidelines given by the Great Lakes Basin Commission. Sources of literature are:

1. USDA, Forest Service Experiment Station Research
2. USDA, Agricultural Experiment Station Research, Michigan State University
3. Water Resources Research Center, University of Minnesota

4. Water Resources Center, University of Illinois

5. Water Resources Center, University of Wisconsin

6. Water Resources Research, Michigan State University

7. Great Lakes Basin Framework Study

8. Abstracts from the Symposium on Management of Municipal Watersheds, 1973, Pennsylvania State University

9. Proceedings of IBP-UNESCO Symposium on Productivity Problems of Freshwaters, 1970, Poland

10. Proceedings of Symposium on Eutrophication: Causes, Consequences and Corrections, National Academy of Sciences, 1969, Wash. D.C.

11. Notes of the American Institute of Biological Sciences Meeting, 1972, University of Minnesota

12. Proceedings of National Symposium on Watersheds in Transition, 1972 American Water Resources Association, Colorado State University

13. Proceedings, Symposium of Forest Fertilization, 1972, Northeastern Forest Soils Group, State University of New York, College of Environmental Science and Forestry

14. Proceedings, International Symposium on Forest Hydrology, 1965, Pennsylvania State University

15. Proceedings, Symposium on Forest Land Uses and Stream Environments, 1970, Oregon State University

16. Proceedings, Governor's Conference on Sediment and Erosion Control, Minneapolis, Minnesota

17. The Environmental Protection Agency STORET Computer Program

Interviews were conducted with personnel located at:

1. North Central Forest Experiment Station, Forest Service-USDA, Maximum Fiber Yield Research Project, Wisconsin
2. USDA-Forest Service, Northeastern Area, State & Private Forestry, Pennsylvania
3. USDA-Soil Conservation Service, State Office, Maryland
4. Michigan Department of Natural Resources, Forestry Division
5. Michigan State University
6. University of Michigan
7. University of Minnesota
8. University of Wisconsin

9. North Central Forest Experiment Station, Forest Service, USDA, Grand Rapids, Minnesota
10. S.D. Warren Company, Michigan

Information was collected and summarized by the individual members and then reviewed and revised by the work group. A draft was made and reviewed by the appropriate Forest Service administrative offices. Further revisions were made and a review draft prepared for the Great Lakes Basin Commission. Again revisions were made and a final Report was prepared for the Commission.

2.4 Assumptions

As stated earlier, research on the impacts of forest activities on water quality in the Great Lakes Basin is essentially nonexistent. Therefore, the following assumptions are made:

1. Processes and relationships of forest activities on water quality in the Great Lakes Basin are similar to those reported in other areas of the nation.

2. Detrimental impacts of forest activities on water quality are less than in other areas of the Nation due to a more favorable geology, climate, topography and soils complex.

3. There is a possibility to cluster-develop urban forest lands, leaving 40 percent in a relatively undisturbed condition.

4. Forest lands subjected to urban construction will react in a similar manner as other lands urbanized for which there is published erosion and sediment research.

5. Initial application of intensive tree culture will be for maximizing fiber yield in the aspen type.

Section 3

REVIEW OF FINDINGS OF PREVIOUS STUDIES

3.1 General Description of Land Use Category

3.1.1 Forest Activities

The major forest land activities in the Basin are timber production, woodland grazing, urbanization, recreation, and wildlife management. It is important to note that at any one time, the vast majority of forest lands are in an undisturbed condition; only 5 percent of the forest lands are disturbed annually due to forest activities.

Timber Production

Activities associated with timber production include harvesting, prescribed burning, site preparation, planting, timber stand improvement, fire control, insect and disease control, and road building.

Harvesting is accomplished by two principal cutting systems: clearcutting, the removal of all trees in a small area; and selective cutting, the removal of individual trees throughout an area. In addition to the removal of trees, harvesting usually includes the construction and maintenance of access roads.

Timber stand improvement and protection includes thinning, timber release, fire protection and insect and disease control. Thinnings and timber release increase the growth of the better trees by removing some of the surrounding vegetation, thus reducing the competition for sunlight, water and nutrients. Thinning usually involves some form of selective cutting but may utilize herbicides. Harvesting trees during thinning operations is usually a timber gain, as the products removed would normally be lost through mortality before the final harvest.

Mechanical site preparation and prescribed burning may be required to remove logging debris and prepare the site for seeding, planting or natural regeneration. Mechanical site preparation usually consists of windrowing logging debris and scarifying the soil with heavy equipment. Prescribed burning is the controlled use of ground fires.

Insect and disease infestations may severely reduce the forest values. Pesticides may be utilized to save the remaining trees or to suppress the infestation until harvesting. The use of pesticides on forest lands in the Basin has been very limited in the past.

Road construction and maintenance have significant hydrologic impacts in forest lands. Access roads built for timber removal, fire control and recreation vary from temporary trails to hard surfaced highways.

Forest Land Grazing

Forest land grazing primarily occurs in the agricultural regions of the Basin in small woodlots and forested stream corridors. These forested areas usually occur where topography, soils or other characteristics are unsuitable for agriculture. Over-grazing is common and results in lower forage productivity and reduced forest values in terms of fiber production, wildlife habitat and soil protection. Livestock and forest production can be compatible, providing good grazing and forest management practices are implemented.

Urbanization

Urbanization will account for the majority of forest land use changes. Forests in and around metropolitan areas are highly desirable for residential development. It is not uncommon to pay 1000 to 2000 dollars extra for wooded lots. Urban development often denudes the land of vegetation, destroys the beneficial hydrologic characteristics of the forest soil complex and replaces these areas with impervious, or nearly impervious surfaces.

Recreation

Most if not all the forest lands in the Basin are increasingly used for recreation. Forest activities related to recreation are the construction, maintenance and/or protection of recreation sites, forest roads and trails and an aesthetically pleasing environment.

Fish and Wildlife Management

Fisheries management includes the maintenance and enhancement of streamside vegetation to maintain cooler stream temperatures and to act as a buffer to reduce sediment delivered to the stream.

Activities relating to wildlife management primarily involves vegetative manipulation for the production, maintenance and protection of favorable and diverse wildlife habitat. This usually involves clearing and/or burning of small areas within forest lands.

3.1.1.1 Past History

Less than two centuries ago the Great Lakes Basin was dominated by a vast primeval forest. The forest consisted primarily of pine, northern hardwoods, and mixed central and northern hardwoods. As early as the 1830's the cultivation of numerous oak savannah openings for agriculture occurred in the southern portions of the Basin.

High quality pine forests in the northern portions of the Basin attracted the beginning of a large lumber industry in 1825. The

Basin's forests supplied much of the nation's lumber from the late 1800's to the early 1920's, the era of greatest expansion. As the timber industry grew it harvested the forest resource at a far greater rate than could be sustained. By 1920 the majority of the virgin forest had been cut and subjected to frequent devastating fires. Agriculture followed on some of these cleared lands but unsuitable soils resulted in the decline of the total tillable acreage well into the 1940's (47).

The lumbering and farm settlement era brought on major changes in water quality. Severe modification and destruction of the natural soil-vegetation complex increased surface runoff and resulted in flooding, excessive erosion and sedimentation, and nutrient release.

A growing concern for dwindling timber and polluted water supplies stimulated Congress to authorize and fund the establishment of national forests under the administration of the USDA, Forest Service. Subsequently, the Superior, Chequamegon, Nicolet, Ottawa, Hiawatha, Huron and Manistee National Forests were created. Following a similar pattern, State Forests were established. Today 4.38 million hectares (10.8 million acres) of forest lands in the Basin are administered by state and federal forestry agencies (47).

3.1.1.2 Present

Approximately 47 percent of the total Basin area is forested. Ninety-five percent of the forest land is classified as commercial: capable of producing industrial wood supplies and not withdrawn from timber utilization through statute, ordinance or administrative order. The remaining lands are non-commercial: incapable of producing wood supplies (47).

Hardwoods occur on 76 percent of the total forest land area, while softwoods (conifers) occupy the remaining 24 percent. Forest types, primarily maple-birch-beech and aspen-birch, are found in the most northerly and elevated portions of the Basin. In the eastern and southeastern portions of the Basin, the dominant forest types are oak-hickory and elm-ash-cottonwood (47).

Coniferous forests are dominated by the spruce-fir and pine forest types. The spruce-fir type, usually occupies poorly drained lowland sites. However, integrated spruce-fir-hardwood stands can be found on well-drained upland sites. The pine type, commonly associated with well-drained sandy sites, is scattered throughout the northern portions of the Basin (47).

The commercial forest land ownership by area and percent is as follows: (47)

Ownership	Area		Percent
	hectares	(acres)	
	- - million - -		
Public			
National Forest	1.9	(4.7)	13
Other Federal	0.2	(0.4)	1
State	2.1	(5.2)	14
Other Public	1.1	(2.6)	7
Private			
Forest Industry	1.5	(3.6)	10
Farmer Owned - Miscellaneous	8.4	(20.9)	55
Total	15.2	(37.4)	100

3.1.1.3 Future

Intensive tree culture is a relatively old concept which may find application in the future. Initial applications will probably be to maximize fiber yields in the aspen type which appears to have the best potential for this type of management. A large pulp and paper industry is well established in the Lake States, and forty-five percent of the annual pulpwood production is from aspen. In addition, aspen reproduces readily by suckering, is fast growing, and occurs in even aged stands; all of which facilitate mechanized harvesting (71).

There are eight million acres of highly productive aspen sites in the Lake States (includes areas outside the Basin)(29). Another four million acres of elm, ash, and cottonwood stands are available for possible conversion. These areas plus existing poorly stocked forest lands and abandoned agricultural lands are potential sites for intensive tree culture.

Forest management practices associated with intensive tree culture are fertilization, irrigation, cultivation, shorter rotations and the use of superior genetic stock. These practices may increase the total quantity of nutrients in the forest system, and create a potential for accelerated losses to surface and groundwater bodies.

3.2 Length of Time Activities in Practice

Harvesting and grazing of forest lands began with the agricultural settlement of the Basin in the early 1800's. From the early 1900's to the latter 1920's forest maintenance and protection were the primary activities. Forest silvicultural practices such as thinning, timber release, prescribed burning, site preparation, planting and seeding, and pest management were initiated on a sizeable scale in the early 1930's. Multiple use management to obtain an optimum balance of high water quality, water yield, recreation, wildlife and wood products has been implemented on state and federal forest lands during the last 15 years.

The concept of maximizing fiber yield through intensive tree culture is still undergoing research and development. However, mechanized logging is already utilized throughout the Basin, and whole-tree harvesting by on-site chipping began in Michigan in 1971 (2). These harvest systems lend themselves to the maximum fiber yield concept and are assumed prerequisites.

3.3 Types and Nature of Pollutants

The release of sediment, nutrients, organic matter, and pesticide residues to the aquatic environment are recognized as serious forms of pollution. Forest activities like other cultural activities accelerate the release of these potential pollutants to surface and ground water resources.

3.3.1 Sediment

The force of raindrops (splash erosion), surface runoff (sheet erosion), channelized flows (rill, gully and streambank erosion) detach and transport material. Once this material is in motion, it is defined as sediment. Sediment is primarily composed of soil aggregates, minerals and organic matter.

3.3.2 Nutrients

Many types of nutrients and elements are released into the aquatic environment. In terms of water quality and eutrophication, Nicholas lists sixteen elements required for algal growth and possibly another eight elements may be needed for certain species of algae (93). However, most of these elements, except phosphrous and nitrogen, are required in such small quantities that they are seldom limiting. Furthermore, it has been discovered that many algal species, especially blue-green algae, can fix atmospheric nitrogen. This means the role of nitrogen in eutrophication may be less important than phosphrous.

Although other nutrient transfers occur, only phosphorous and nitrogen release will be considered in relation to forest activities.

3.3.3 Organics

Organic material, found in lakes and streams draining forested areas, originates from direct leaf fall into these surface waters and decomposing vegetative matter, organic colloids, and dissolved organics in forest runoff. This organic matter contributes to the biological oxygen demand and reduces the oxygen content of receiving lakes and streams. In most cases this organic material is an important source of energy for aquatic communities.

A considerable amount of dissolved organic material is highly colored and will stain water yellow to dark brown. This material consists primarily of phenolic derivatives, carboxylic hydroxides, tannins, celluloses, and humic acids. The significance of water color is its influence on light penetration; the spectral composition of the euphotic zone and aesthetic qualities of water bodies.

3.3.4 Herbicides

The principal herbicides used in forestry are 2,4-D and 2,4,5-T. These are selective hormone-type phenoxy compounds applied as low volatile esters. Both of these compounds are moderately to slightly toxic to non-target species and decompose in three months or less.

Cacodylic acid is also used in significant quantities in single stem treatments. This herbicide is mildly toxic and has a very short life span.

Simazine and picloram are also used but their applications are limited due to their persistency (over one year). However, the toxicity of these herbicides to non-target species is low.

Many other herbicides are available, such as Dalapon, Bromacil, Monuron, Atrgine, Atrazin, and Amitrol, but they are not used in significant quantities in forested areas.

3.3.5 Insecticides

There are two classes of insecticides, inorganic and organic. Lead arsenate was the most widely used inorganic insecticide during the early years of spraying but has been used very sparingly if at all, in the last 25 years. Inorganic insecticides have very little solubility in water and remain where applied (38). The new organic insecticides such as malathion, aldrin, and DDT have varying degrees of stability in the environment (38). Some insecticides such as Aldrin have high biomagnification potential in the food web and are quite toxic to some forms of wildlife.

3.4 State of the Art in Assessing and Quantifying Problems

3.4.1 Sediment

Sediment is considered one of the nation's greatest water pollutants. It has been estimated that four billion tons of sediment are washed into the nation's waterways and reservoirs annually. This is equivalent to four million acres of soil six inches deep (84). Sheet and gully erosion are considered the primary contributors. In addition to cultivated lands, urban areas, and construction projects, the improper use and management of forest lands can contribute considerable quantities of sediment to surface waters.

On-site erosion damages include the loss of top soil, lower site productivity, scarred topography, degradation of aesthetics, and inoperable roads. Downstream damages include impairment of aquatic life, increased costs of downstream water treatments, increased downstream flooding, diminished aesthetic qualities, and reduced channel, reservoir and lake capacities. In addition, sediment can be a carrier of nutrients, pesticide residues and harmful pathogens.

Stream sediments increase turbidity and decrease sunlight penetration and solar energy to photosynthetic organisms. This can disrupt the basic elements of the aquatic food chain. Such disruptions may result in reduced numbers and diversity of aquatic populations. Excessive sedimentation can destroy food, eliminate cover, and bury spawning beds (61) (66).

Sedimentation in the Great Lakes Basin is a relatively minor problem. Variations in nationwide suspended sediment loads are as follows (97):

Region	Suspended Sediment Concentration (mg/liter)
Lake States	less than 300
New England	less than 300
Southeast	less than 300 to 2000
Central Corn Belt	300 to 5000 plus
Great Plains	300 to 30,000
Southwest	2000 to 50,000
Pacific Northwest	less than 300

Average annual sediment concentrations have been mapped for the United States. Practically all of the Great Lakes Basin is in the lowest category of up to 280 ppm. A small portion of the Basin in the Detroit-Ann Arbor-Toledo area is in the next higher category of 280 to 2000 ppm (104).

Sediment yield rates for watersheds primarily under 259 square kilometers (100 square miles) in area throughout the nation varied from 178 metric tons (1 km^2/yr)(509 tons/mi^2/yr) in the Lake States and Northeast; to 5,932 metric tons/km^2/yr (16,950 tons/mi^2/yr) in the Mississippi Valley (77).

The current average annual gross erosion rate for the entire Great Lakes Basin is approximately 4.03 metric tons per hectare per year (metric tons/ha/yr)(1.80 tons per acre per year). This rate varies from 0.2 metric tons/ha/yr (0.1 tons/ac/yr) in the northern forested areas to 18 metric tons/ha/yr (8 tons/ac/yr) in the intensely cultivated southern parts of the Basin. The long time average annual sediment yield rates from some of the larger drainage areas range from 0.7 to greater than 70.0 metric tons/km^2/yr (2 to 200 tons/mi^2/yr) (45)(26)(27)(128).

The St. Louis River in Minnesota yields approximately 1.05 metric tons/km^2/yr (3 tons/mi^2/yr), while the Maumee and Cuyahoga Rivers in Ohio yield 60.6 and 88.9 metric tons/km^2/yr (173 and 254 tons/mi^2/yr) respectively (45).

The basin reason the Great Lakes Basin yields less sediment is the geologic structure of the Basin. Topography of the Basin is characteristically flat with low relief, thus reducing surface runoff. A large proportion of the Basin is covered by a deep mantle of sandy glacial drift. This condition is favorable to high soil infiltration rates (49). In other areas, the erosion of a heterogeneous mantle of glacial till exposes the pebbles and boulders which in turn divert surface runoff and reduces its velocity. If gullying occurs, the gully bottom soon becomes protected by a pavement of gravel (77).

3.4.1.1 Land Use

Land use in a watershed is highly correlated with sediment yield. The following conclusion correlating land use to sediment was reported by Striffler in 1964:

> "Sediment discharge rates increase with increasing proportions of cultivated and pasture land and decrease with increasing proportions of forest and wildland". (115)

In support, Lull and Reinhart in 1972 reported the following:

> "Other things being equal, the greater the proportion of cropland, the greater the sediment yield". (77)

With reference to forest lands the following relationship was determined for an area in the Potomac River Basin:

Percent Forest Cover	Sediment Yield	
	metric tons/km^2/yr	tons/mi^2/yr
20	140	400
40	70	200
60	32	90
80	16	45
100	8	22

A five-fold increase in forest land could produce an 18 fold decrease in sediment (77).

The calculated sediment yield rates by planning area in the Great Lakes Basin ranged from 0.02 metric tons/ha/yr (0.01 tons/ac/yr) in planning area 1.2 (93 percent forested), to 0.62 metric tons/ha/yr (0.28 tons/ha/yr) in planning area 2.2 (9 percent forested). The mean sedimentation rate was 0.16 metric tons/ha/yr (0.071 tons/ac/yr) (27).

The following maximum sediment yield rates were reported for an area in the Northeast having 15 inches of annual runoff (76):

Use	Concentration ppm	Sedimentation Rate	
		metric tons/ha/yr	(tons/ac/yr)
Forest Land	45	112	(50)
Established Urban-Suburban	90	112-224	(50-100)
Farmland	4,500	2240-11200	(1000-5000)
Urban-Suburban Construction	45,000	56000-112000	(25000-50000)

Maximum sediment concentrations from several land uses in a Wisconsin study were as follows (77):

Watershed Use	Suspended Sediment Concentrations ppm
Undisturbed Forest	100
Old Field	300
Logged Forest	3,600
Lightly Grazed Pasture	13,000
Alfalfa Meadow	19,800
Heavily Grazed Woodland	55,900
Heavily Grazed Pasture	82,000
Clean Tilled	238,000

25¢

Sediment yield rates for various land use classes in the Tobacco Watershed in northern Lower Michigan were as follows (115):

Use	Sedimentation Rates	
	metric tons/ha/yr	tons/ac/yr
Wildland[1]	0.04	0.02
Forest	0.22	0.10
Pasture	1.14	0.51
Cultivated	1.41	0.63

---

[1] Brush lands, non-forested bogs or swamps abandoned land and other idle land.

Urbanization has the greatest hydrologic impact in a watershed and is a major source of water pollution (80). The urbanization of forest lands in the Basin will account for the majority of forest land use conversions. Urban erosion and sediment are discussed in terms of established areas and areas undergoing construction.

Researchers in the East and Midwest have reported tremendous increases in sediment yields due to urban construction (76). Erosion rates in construction areas may be 20,000 to 40,000 times that from adjacent farm and forest lands (80). Within the Basin, sediment production from urban construction activities in the Detroit metropolitan area, covering 2.1 percent of the watershed was 154.0 metric tons/ha/yr (69 tons/ac/yr) and nearly equal to the total yield from the remaining 97.9 percent of the area (77).

Once established, urbanized areas may produce more or less sheet erosion and sediment than adjacent farm and forest land. Substantial coverings of urban lawns and asphalt, concrete and other impervious surfaces stabilize the soil beneath very efficiently (77). A comparison of average sediment yield rates from metropolitan complexes in the Basin under construction and after establishment are 33,600 and 45 metric tons/km^2/yr (96,000 and 129 tons mi^2/yr) respectively.

3.4.1.2 Undisturbed Forest Lands, Natural Background Contribution

The total vegetative cover, and deep rooting systems of forest lands provide maximum protection against surface runoff and erosion. Infiltration capacities of most forest floors exceed precipitation intensities. Overland flows are largely absent even during flood producing conditions. When overland flow does occur it is usually in small localized sections. These flows rarely become channelized and are usually absorbed by the litter downslope. Erosion from undisturbed forest lands occurs almost entirely within the stream channel (26)(77)(82).

Examples of forest sediment yield rates from undisturbed forest lands are as follows:

	Investigators	Location	Sedimentation Rate/Concentration
1.	Reinhart and Others (1963)(76)	Fernow, W.Va.	mean turbidity 5 ppm 2.45 metric tons/km^2/yr (7 tons/mi^2/yr)
2.	Wolman and Schick (1967)(76)	Kentucky	5.25 metric tons/km^2/yr (15 tons/mi^2/yr)
3.	Anderson and McCall (1966)(77)	New Jersey forest and flatland	3.5-14 metric tons/km^2/yr (10-40 tons/mi^2/yr)
4.	Dils (1957) (15)(98)	Coweeta N.Carolina	normal turbidity 2 ppm storm events 11 ppm extreme events 80 ppm
5.	Lull and Reinhart (1963) (15)(98)	Hubbard Brook New Hampshire	non-storm turbidity 1 ppm storm turbidity 11 ppm

Undisturbed forest lands in the Great Lakes Basin have been estimated to erode at a normal or geologic rate of 0.36 metric tons/ha/yr (0.16 tons/ac/yr). The sediment yield rate from these lands to forest streams is estimated at 0.015 metric tons/ha/yr (0.0067 tons/ac/yr) (45)(26)(27)(128).

3.4.1.3 Forest Harvesting

The construction of logging roads and the movement of logs and machinery over a harvest site churn up the surface soil exposing areas of mineral soil. Soil infiltration rates on disturbed areas can be so reduced that surface runoff and erosion result. Soil compaction resulted from both winter and summer mechanized logging operations in north central Minnesota (81). Soil infiltration rates were reduced 70 to 100 percent on the heavy to medium disturbed areas. Recovery was minimal after one overwintering period (81).

Not all particles carried in overland flow reach forest streams. The filtering action of the forest floor traps most of the sediment. If soil infiltration rates remain high, the chances of accelerated sedimentation are minimal (26).

Packer stated the following:

> "Some soil disturbance is only short-term temporary baring (of surface soil). Frequently, the beneficial effects of shallow disturbances, such as increased impressional storage may offset any deleterious effects caused by soil compaction, such as reduced pore space." (98)

The removal of trees per se does not result in accelerated sheet erosion. This conclusion has been published from studies in New Hampshire, North Carolina, West Virginia, and Colorado (26)(77)(98).

More and more evidence attributes increased erosion and sedimentation to logging roads and skid trails during harvesting and for a limited period thereafter. The severity of this impact depends on the areal extent, location, drainage and maintenance of the logging roads and skid trails (98).

Logging roads not only intercept surface flows, but also subsurface flows in shallow soils or steep topography. In the steep western mountainous areas, water yields from roads were 7.3 times greater than estimated road surface runoff based on rainfall interception (86). As much as 15 percent of the total precipitation can be transmitted laterally downslope, within the top 12 inches of soil (98).

The most important factor affecting the impact of logging roads is the total area they disturb. This depends on the degree of planning, topography, type of logging and cutting system. The areal extent of skid trails and roads by various harvesting systems in a West Virginia study are as follows (26):

Cutting System	All Roads	Bulldozed Skid Trails
	- - - - percent of area	- - - -
Commercial clearcut	7.3	3.6
Diameter limit	6.2	2.5
Extensive selection	5.9	2.1
Intensive selection	1.9	0.8

In the H.J. Andrews Experimental Forest, Oregon, 62 percent of a harvested area was disturbed by tractor logging. Of this 27 percent was severely disturbed (98).

In a harvest operation of ponderosa pine in the Pacific Northwest it was determined that 15 percent of the soil surface suffered deep disturbances from tractor logging. In a similar study, soil disturbances were related to the number of trees cut and silvicultural method used. Single tree selection produced 36% more disturbed area than did group selection. This difference was attributed to longer skidding distances (98).

Logging systems and their effect on forest land erosion and sedimentation varies. All of the following studies from areas throughout the country show accelerated sedimentation to some degree. Again, roads and skid trails are considered to be the primary contributors.

Location	Sedimentation Yields	
	Harvest Area	Control Area
1. North Carolina (77)	7,000 ppm maximum 93 ppm average	93 ppm maximum 4 ppm average
2. North Carolina (98)	3,500 ppm maximum 94 ppm ave. storm	80 ppm maximum 4 ppm average
3. Georgia (77) careful logging	5 ppm average	4 ppm average
4. Idaho (98) Highly erodable soils 1st season after logging (3 separate measurements)	1. 27,800 metric tons/ha/yr (12,400 metric tons/ac/yr) 2. 19,940 metric tons/ha/yr (8,900 tons/ac/yr) 3. 200 metric tons/ha/yr (89 tons/ac/yr)	----
5. Colorado (77)	56,000 ppm maximum 1st yr 490 ppm average 1st yr after 2nd yr 38 ppm ave. after 3rd yr 1 ppm ave.	----
6. West Virginia (74) 4 levels of management and methods	56,000 ppm maximum 5,200 210 25	15 ppm maximum

At the Fernow Experimental Forest, West Virginia, managed harvests with well constructed skid trails (gradients less than 10 percent and drained by water bars) produced 62 kilograms of sediment per hectare (55 lbs/ac) the first year after logging. In contrast, poor road design (no limits on gradients and no water bars) produced nearly 8 times the sediment at a rate of 485 kilograms per hectare (433 lbs/ac) (98).

3.4.1.4 Forest Land Grazing

Excessive woodland grazing destroys natural cover, reduces humus and litter surface layers, and compacts the soil. The grazing intensity at which accelerated sedimentation is initiated varies and is difficult to predict. The lack of data on woodland grazing may indicate that the initiation of accelerated sediment production is slow and not of great magnitude (77). Grazing, however, can be correlated with forest humus reductions and soil compaction; two important characteristics in accelerated erosion and sedimentation prevention. Decreased ground cover and increased soil compaction, surface runoff, and erosion due to woodland grazing has been reported (63)(77)(109).

Woodland grazing on the Coweeta Experimental Forest, North Carolina, had very little effect on accelerated sedimentation until the overland flows finally reached the stream during the ninth successive year of grazing. During this period, soil infiltration rates and ground cover were slowly reduced. Eventually surface flows normally absorbed by the forest floor emptied into the adjacent streams. The maximum sediment concentrations for one particular storm was 108 ppm as compared to adjacent undisturbed forest lands at 38 ppm (77). Sediment production in a grazed Wisconsin hardwood stand was determined to be at a rate of 0.31 metric tons per hectare per year (0.14 tons/ac/yr) (77). In northern Mississippi, the erosion rate from a small pastured watershed averaged 3.6 metric tons/ha/yr (1.6 tons/ac/yr), eight times the rate from a protected forested watershed (77). Finally in another Wisconsin study, maximum sediment concentrations from grazed and ungrazed watersheds were 55,900 and 100 ppm respectively (77).

3.4.1.5 Wildfires and Prescribed Burning

An occasional wildfire or prescribed burn in the Great Lakes Basin will rarely initiate overland flow or accelerated erosion. Repeated burning, however, will remove the forest litter and humus and eventually produce substantial volumes of surface runoff and sediment. In North Carolina, woodland plots were burned semi-annually. Erosion rates increased over time: first year 0.22 metric tons/ha (0.1 tons/ac), second year 0.67 metric tons (0.3 tons), third year 2.33 metric tons (1.04 tons), fifth year 8.74 metric tons (3.90 tons), and the sixth through ninth years 11.20 metric tons (5.0 tons)(77).

Soil losses from burned and protected woodlands were cited by Ralston and Hatchell as follows (103):

Investigator	Location			Soil Loss Metric tons/ha/yr	(tons/ac/yr)
Meginnis	Mississippi		Burned	0.74	(0.33)
			Protected	0.06	(0.025)
Daniel	Oklahoma		Burned	0.25	(0.11)
			Protected	0.02	(0.01)
Copley	North Carolina		Burned	6.90	(3.08)
			Protected	.004	(0.002)
Pope	Tyler, Texas		Burned	0.81	(0.36)
			Protected	0.11	(0.05)
Ferguson	East Texas		Burned	0.47	(0.21)
			Protected	0.22	(0.10)
Ursic	North Miss.	(1st yr)	Burned	1.14	(0.51)
			Protected	0.45	(0.20)
		(2nd yr)	Burned	0.11	(0.05)
			Protected	0.47	(0.21)
		(3rd yr)	Burned	0.20	(0.09)
			Protected	0.07	(0.03)

In the Great Lakes Basin almost all forest lands are adequately protected through federal-state control programs. Fires still occur but primarily as small scattered events. Burned areas usually revegetate naturally in 4 to 6 years.

3.4.2 Nutrients

Determining the effects of forest activities on water quality is best accomplished through a nutrient budget approach. Nutrient inputs to a particular site are primarily from precipitation and/or fertilization. Nutrient outputs are primarily from soil leaching, soil erosion, leaf fall into surface waters and tree harvesting. The amount, degree, and frequency of forest land manipulation is minimal. Consequently, forest land drainage usually reflects baseline water quality.

3.4.2.1 Undisturbed Forest Lands, Natural Background Contributions

The quality of water draining undisturbed forested areas is largely a function of atmospheric inputs, geologic weathering of rock and soil, and biological activities. Cole demonstrated that forests on the Cedar River Watershed (Douglas fir ecosystem: Washington) are almost a closed system with minimal nutrient losses to surface and groundwater (20). A review of nitrogen and phosphorous losses from forest lands in and around the Great Lakes Basin indicated very small losses. Examples are as follows:

Streamflow Output of Nutrients

Investigator	Location	Nitrogen	Phosphorous
		- - Kg/ha/yr (lbs/ac/yr) - - -	
Pierce 1973 (100)	N.H.	1.8 (1.6)	.02 (.02)
Frink 1971 (41)	Conn.	3.4 (3.0)	.24 (.21)
Frink 1971 (41)	Md.	1.6 (1.4)	.10 (.09)
Frink 1971 (41)	Minn.	3.5 (3.1)	.13 (.12)
Barton 1969 (7)	N.E. Minn.	1.1-2.9 (1.0-2.6)	.08-.19 (.07-.17)
Taylor 1971 (120)	Ohio	2.9 (2.6)	.05 (.05)
Sylvester 1961 (119)	Ohio	2.4 (2.1)	.80 (.70)
Schindler 1972 (110)	N.W. Ont.	3.0 (2.7)	.10 (.90)
Crumrine 1973 (24)	Mich. U.P.	- -	.10-.30 (.90-.27)

In a study conducted in Wisconsin, only 0.5 percent of the nitrogen and 0.3 percent of the phosphorous were contributed by forest lands. Unfortunately, the ground water component which contributed 42 percent of the nitrogen but only 2.3 percent of the phosphorous was not broken down as to source (41).

Geology and soils are often cited as prime influences of water quality (21). However, phosphorous and nitrogen outputs can apparently be accounted for by meteorological inputs (21)(73). A review of the meteorological inputs of nitrogen and phosphorous showed that 3.5 to 10.0 kg/ha/yr (3.1 to 8.9 lbs/ac/yr) total nitrogen and 0.1 to 1.0 kg/ha/yr (0.09 to 0.89 lbs/ac/yr) total phosphorous are realistic meteorological inputs in the Great Lakes area (16). Forest phosphorous and nitrogen outputs appear to be in near equilibrium with inputs when reductions of nitrogen through volatilization, dentrification, and vegetative uptake are identified. Total phosphorous concentrations range from less than 0.01 mg/l to greater than 0.10 mg/l and total nitrogen concentration from less than 0.25 mg/l to values exceeding 5.00 mg/l (EPA STORET System). Lower concentrations are characteristic of oligotrophic lakes and higher values of waters draining wetland areas (133)(67).

3.4.2.2 Forest Harvesting

Forest harvesting may accelerate nutrient release to streams. When trees are harvested, nutrient assimilation by vegetation is reduced, soil temperature and water content are increased, and forest litter (logging slash) accumulates. These components accelerate the microbial decomposition of organic debris. Nutrient can then be easily leached or eroded along with mineral matter from disturbed areas. Annual nitrogen losses after harvesting were reported in the following studies:

Investigator	Location	Treatment	Form	Nitrogen Loss	
				Kgm/ha	(lbs/ac)
Brown (1973)	Oregon	clearcut & burned	NO_3-N	(13.5)	(12)
(15)	Oregon	patchcut	NO_3-N	(1)	(1*)
Cole (1965)(18)	Wash.	clearcut	Tot-N	(1)	(1)
(1970)(19)	Wash.	complete tree removal	NO_3-N	(27)	(24)
Aubertin(1972) (4)	W.Va.	clearcut	NO_3-N	(3.4)	(3)
Douglass(1972) (32)	N.C.	clearcut	NO_3-N	(1)	(1)
Reinhart(1973) (105)	N.H.	clearcut	NO_3-N	(38-57)	(34-51)
Likens (1970) (69)	N.H.	complete devegetation	Tot-N	(128-180)	(113-160)
Fredrickson (1971)(40)	Oregon	clearcut & burned	Tot-N	(5.6)	(5)
Verry (1972) (133)	Minn.	clearcut	Tot-N	(1)	(1)
DeByle(1972)(31)	Mont.	clearcut & burned	Tot-N	(9.5)	(8.5)

All sources agree that harvesting will accelerate nutrient release to adjoining streams and lakes if losses are expressed as areal losses over time.

Though harvesting results in an increase in the mass transport of nutrients leaving the cut area, the effect of cutting on nutrient concentration in surface waters draining these areas is far less clear. Increased nutrient losses as a result of timber cutting are diluted by the associated increase in water yield (55). In some measurements an actual decrease in stream nutrient concentration has been reported while in other measurements only a slight or no increase has been found (42) (4)(116). Significant nutrient increases, especially in nitrogen have been reported in experiments where total devegetation was maintained by the use of herbicides. This condition is unusually severe and unlikely to occur during or after normal forest harvesting (100)(12)(40). It is generally concluded, however, that cutting has only a short term effect on water quality and that the effect is highly variable. In relation to clearcutting, selective cutting and strip-cutting should have a reduced impact.

3.4.2.3 Site Preparation

After harvesting, most areas require additional preparation for timber regeneration. This usually involves mechanical clearing and scarification, burning, and the application of chemical herbicides, individually or in combination. Mechanical methods include roller chopping, rock raking, root raking, harrowing, cultivating, furrowing, tilling, bulldozing, and chaining. Prescribed burns are utilized to remove logging slash, reduce forest fuels and expose mineral soil for adequate seedbeds. Herbicides are seldom used and will be covered in section 3.4.4.

Activities associated with site preparation may have a greater impact on water quality than tree harvesting (52). These activities usually result in a considerable amount of soil disturbance which will influence the rate of erosion. Nutrient losses associated with erosion have been documented for various agricultural activities (6)(11)(58)(119)(124). In agricultural lands, soil erosion appears to be the primary route for phosphorous loss and a significant source of nitrogen input to lakes and streams. Unfortunately, similar data on erosion-associated nutrient losses from forest activities do not exist.

3.4.2.4 Intensive Tree Culture

Maximum fiber yield management would almost certainly require clearcutting at harvest time. The previous data indicate that clearcutting has the potential for accelerating nutrient release. Unfortunately, no studies have yet been completed on this problem in the Basin nor the timber types of interest. Therefore, the effects and degree of alternative management practices on nutrient release and water enrichment is not known. One study, however, is underway (Richardson, personal communications).

Cutting methods used in intensive tree culture will probably remove more nutrients from the site than will conventional methods. Data on the total nutrient contents of different size trees of different species together with Michigan aspen stocking information provides the following gross estimates of nutrient contents of good to well-stocked aspen stands (142)(91).

	N	P
	Kg/ha	(lbs/acre)
Total in stand	453 (404)	47 (42)
Removed by:		
Total tree chipping	276 (246)	33 (29)
Conventional logging	138 (123)	16 (14)
Total tree chipping with bark separation	122 (109)	13 (12)

Although these estimates require several assumptions as to stand characteristics, the "total stand" values compare favorably with other published data (118)(83).

Conventional logging of aspen removes only about one-third of the nutrients present in the entire tree. Total tree harvesting (including bark) doubles the nutrient removed from the site. Total tree harvesting with on-site debarking would have about the same effect on nutrient drain as does conventional logging. The nutrients in the trees generally represent only a small fraction of the total present on the site. This is illustrated by the following data (20):

Ecosystem	Nitrogen			Phosphorous		
	kg/ha	(lbs/ac)	Percent of total	kg/ha	(lbs/ac)	Percent of total
Forest	320	(285)	9.7	66	(59)	1.7
Subordinate Vegetation	6	(5)	0.2	1	(1)	0.1
Forest Floor	175	(156)	5.3	26	(23)	0.6
Soil	2809[1]	(2500)	84.8	3878[2]	(3451)	97.6

[1] Total

[2] Exchangeable with pH 7 ammonium acetate

Nutrient removal from harvesting must be eventually balanced with inputs from precipitation and fertilization to maintain or enhance site productivity. Soils generally have a considerable capacity for immobilizing phosphates, and large quantities would have to be added before leaching would occur (1). On the other hand, excessive NO_3 fertilization will usually result in leaching losses with potentials for ground water enrichment. Fertilization of a watershed in West Virginia with 210 kg/ha (187 lbs/acre) of nitrogen increased the stream Nitrate-N discharge the first year by a factor of 10 to an average concentration of 5 mg/l (5). Eighteen percent of the nitrogen applied as urea was discharged in streamflow. In contrast, fertilization rates of 55 kg/ha (49 lbs/ac) of nitrogen in central Washington yielded only 0.001 percent

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of the total applied to streamflow during the first two months following fertilization with a maximum concentration of 0.2 mg/l (62). In either case the quantities released posed no significant threats to water quality.

The amount of fertilizer added to field trial plots of a current maximum fiber yield experiment are 26 kg/ha/yr (23 lbs/ac/yr) nitrogen and 67 kg/ha/yr (60 lbs/ac/yr) phosphorous (Dave Dawson, personal communications). These quantities are continually adjusted, according to the nutrient content of the soil and vegetation. Forest fertilization trials elsewhere in the United States have often used considerably heavier applications (121).

A summarization of work done on effects of forest fertilization on water quality states: "The few...studies conducted to date indicate that toxic levels are not approached in natural water supplies and that the total applied nutrient loss is inconsequential" (35). However, the authors go on to say that: "Increasing use of forest fertilization in certain areas...could conceivably cause toxic or eutrophic consequences..." (35). The West Virginia study noted above illustrates this possibility.

3.4.2.5 Forest Fire

Fire, in the form of prescribed burning, is used for slash removal, regeneration, and reducing fuel accumulation. Recently it has been considered as a forest ecosystem management method (60)(48)(54)(108).

Burning of terrestrial vegetation has been regarded as a very significant potential source of nutrients. The generation of large amounts of water soluble nutrients after burning that were previously organically bound could significantly increase the release of nutrients to streams. In one study increased nutrient losses of 1.6 to 3.0 fold were measured from an area clearcut and burned (40). Increases in dissolved solids of from 480 to 3,000 mg/liter were measured from a burned brushland forest in southern California (74). In contrast, no change in water quality was found following a forest fire at Sagehen Creek, California (57). In northeastern Minnesota, little, if any, change in nutrient concentrations were measured in small lakes after a large wildfire (6,000 hectares or 14,830 acres)(78). In other studies, observed increases in erosion imply potential increases in nutrient losses (132)(103)(31). Research on the effects of forest burning on water quality is at best inconclusive.

3.4.3 Organics

Inputs of organic matter from forest lands to lakes and streams can be considerable. Organic inputs appear to be a very important souce of energy in many aquatic ecosystems (68)(43)(138).

Much of this material can stain water yellow to dark brown. These colored organic compounds can be found in fairly high concentration in many streams and lakes. Particularly high color levels are found in water draining perched peat bogs (133). Many of these substances appear to be the products of vegetative decomposition and are very resistant to further decomposition.

In one study 99.8 percent of the organic matter present in a study stream originated from the surrounding watershed (37). Organic terrestial inputs of over 60 kg/ha/yr (54 lbs/ac/yr) from an undisturbed forest into a stream were measured in the Hubbard Brook Experimental Forest, New Hampshire (13). Autumn leaf fall has also been shown to release nutrients, organic matter, and color material in sufficient quantities to alter the chemistry of small lakes and streams (23)(124)(137)(112).

Organic losses associated with forest activities such as harvesting and grazing have been suspected. The increased microbial activities in the forest soil and litter after harvesting and during grazing should result in the loss of dissolved organic matter. Organic losses doubled during each of two years following harvest operation in areas of the Hubbard Brook Experimental Watershed, New Hampshire (69)(14). Unfortunately, other investigators have not quantified organic losses resulting from timber harvesting and this effect remains largely unknown.

3.4.4 Herbicides

Herbicides are primarily used for timber release and thinning. However, herbicides are also used for brush control near roads and rights-of-way, wildlife habitat manipulation, and recreation site maintenance. Applications are made by aerial or ground spraying, and by individual stem treatment.

An excellent review of the impacts of herbicides used in forest activities has been written by the Forest Service, Final Environmental Impact Statement for Herbicide Use in Eastern Region (Region Nine)(127). Herbicides reach surface waters through accidental direct application, aerisol drift and/or in conjunction with surface eroded material (95)(89)(96). Low levels of stream contamination were reported after a helicopter spray project in Oregon (73). Little or no surface water contamination was found while monitoring spray applications on Forest Service projects throughout the East. Herbicides used in forestry activities are generally low in toxicity, exhibit limited persistence and are found in minor concentrations, if at all, after use (100)(92)(89)(96). Most evidence suggests that the risks of surface water contamination are low when herbicides are properly applied (90)(102)(89).

3.4.5 Insecticides

Approximately 15.1 million hectares (37.4 million acres) of commercial forest lands occur in the Basin. Figures are available for insecticide use on 2.3 million hectares (5.8 million acres) of land under the administration of the U.S. Forest Service. During the forty year period from 1934 to 1973, 134 thousand hectares (330 thousand acres) or 5.7 percent of the federally owned lands have been sprayed with insecticide (39). Expanding these figures to include all ownerships, an estimated 0.9 million hectares (2.3 million acres) of forest lands have been sprayed. Less spraying has occurred on state and private ownerships than on the national forest lands.

DDT at an average rate of 1.1 kilograms per hectare (1 lb/ac) was applied on the majority of federal lands sprayed between 1945 and 1964. No doubt this was true for the non-federal ownerships also. Lead arsenate was used before 1945. Malathion was substituted for DDT in the early 1960's. Aldrin was used for the control of soil insects on 5.1 thousand hectares (12.6 thousand acres) of federal land and some Michigan and Wisconsin state lands from 1960 to about 1967.

3.5 Mobility of Pollutants within Soil-Water, Groundwater and Surface Water Systems

When forest derived pollutants such as sediment, nutrients, organic matter, and pesticide residues are released to the Basin's water system, their movement and detection is probably indistinguishable from similar pollutants of agricultural or urban origin.

3.5.1 Sediment

Water in the form of precipitation and channelized and surface flows can detach and transport organic and mineral matter by splash erosion, suspended sediment discharge, and bed load movement. Splash erosion is the spattering of small soil particles due to the impact of raindrops. These particles may or may not be transported later by surface runoff. Suspended sediment discharge is the transport of mineral and organic solids held in suspension by the upward components of turbulent currents of fluid flows. Bed load movement is the transport of particles essentially in continuous contact with the surface or streambed, by sliding, rolling or skipping due to fluid flows and gravity.

In Michigan sand-size particle transport was found to occur during low flows (51). This indicates that once sediment reaches a perennial stream, it is highly mobile. In the Great Lakes Basin, one estimate of the annual sediment yield from sheet erosion is 4.1 million metric tons (4.5 million tons). Forest lands are estimated to account for 5 percent of this total (Mildner, personnal communications).

3.5.2 Nutrients and Organics

Nutrients can be transported by soil and litter leaching, surface runoff and erosion. Nitrogen and organic matter are principally transported by leaching, surface runoff, and erosion. Phosphorous is primarily lost through the process of erosion, with lesser amount dissolved in surface runoff.

In comparison with agricultural lands the mobility of nutrients within the forest lands differ in several ways. Forest vegetation is relatively permanent. This allows a litter layer to be formed which creates a nutrient reservoir. This process is disrupted by disturbances such as timber harvesting, burning, excessive grazing and intensive recreation. These disturbances result in the mechanical and biological breakdown of the litter and humus layers (79). This in turn frees nutrients for leaching, and erosion transport with the potential to enrich surface and ground waters as previously cited. In addition to water transport, considerable quantities of nutrients may be moved on fly ash by thermal and wind currents during burning.

3.5.3 Herbicides

Herbicides primarily reach surface waters by accidental direct application and aerosol drift. Aerosol drift is the lateral movement of sprayed herbicide droplets too small to fall directly to the target area. These droplets can be held in suspension and transported considerable distances by air currents. The proper application and spraying conditions can eliminate or greatly reduce this loss. Other transport mechanisms (of probable minor importance) are surface runoff and erosion and possibly leaching to ground waters (not documented).

3.5.4 Insecticides

Insecticides "disappear" from the target area in several ways. Most of the research dealing with this "disappearance" has been concerned with the residues left and their insecticidal effectiveness rather than the transport of the chemical.

The two classes of insecticides, inorganic and organic, have fundamental differences in their stability. Inorganic insecticides have very low solubility in water, and remain where applied (38).

The newer organic insecticides such as malathion, aldrin and DDT, have varying degrees of stability in the environment (38). Malathion, an organophosphorous insecticide which has replaced DDT, is readily oxidized and hydrolyzed and thus is not persistent in the environment (38). The oxidation products are not known to be toxic.

The persistence of aldrin, a chlorinated hydrocarbon, is affected by soil moisture by displacing the aldrin from soil particles (70). Once this happens, the aldrin is volatilized into the atmosphere. Aldrin also converts to its epoxide, dieldrin, which is also an insecticidal chemical (38). In the Illinois corn belt 15-30 percent of the aldrin applied was converted to dieldrin, and a larger percentage was probably lost to evaporation. One year after application 10 to 15 percent of the aldrin and dieldrin residue remained (30).

DDT, a chlorinated hydrocarbon, is almost insoluble in water and is not subject to hydrolysis. Following a forest spraying project in New Brunswick, DDT residues were found only in the surface few inches of soil. DDT losses were detected but not by leaching (143). DDT is so extremely hydrophobic that molecules in solution migrate to a water-air surface where codistillation takes place. The DDT is evaporated into the air along with water molecules at a much greater rate than expected from its very low vapor pressure. Once the DDT is in the air, the catalytic action of the sunlight promotes its destruction by oxidation (38). Organic matter, including the litter on the forest floor, apparently binds or otherwise makes the DDT unavailable as an insecticide (143). In support the results of another study indicated no volatilization of DDT from the soil (54). Although insecticides cannot disappear from the ecosystem short of complete degradation, significant amounts can be transported by sheet erosion.

3.6 Natural Renovation Mechanism Available to Remove Pollutants and Contaminants

Natural renovation is an inherent forest characteristic. Sediment and nutrient loss is primarily a result of vegetative removal and its associated soil disturbances. The establishment or re-establishment of forest vegetation is a primary objective of forest management. Regeneration of forest cover provides soil protection, greater soil infiltration and closes the nutrient cycle again. Accelerated sediment and nutrient loss from periodic disturbances such as logging and fires are transient events. However, long time disturbances such as forest grazing may produce continual accelerated nutrient and sediment losses. Based on forest water yield and erosion studies, it appears that disturbed forest lands will naturally renovate to near predisturbance conditions in 4 to 6 years (26)(128)(75)(77)(103).

The most commonly used herbicides, 2,4-D and 2,4,5-T, are usually inactivated by microbial degradation in the soil usually within three months. The decomposition products of phenoxy compounds are carbon dioxide, inorganic chlorides and water (141). Toxic or persistent intermediate breakdown products have not been reported for the herbicides used in forest treatments. In water, herbicides also decompose rapidly. However, significant concentrations (58.8 ppm) of 2,4-D have been found in sediment samples 10 months after application (101).

Ordinarily insecticides move only short distances in the soil even after months of leaching conditions. Substantial amounts of chlorinated hydrocarbon residues may persist in the soil for months or years. Although insecticide residues cannot disappear from the ecosystem short of complete degradation or removal from the site by runoff, the presence of insecticides in surface waters reaches low often undetectable levels in a short time after application. In terms of water quality it appears that the forest renovation system (actually an insecticide sink) is adequate.

3.7 and 3.8 Probable Changes in Land Use and Projected Forest Land Pollution Problems

The total forest land acreage will remain essentially stable over the next 40 to 50 years based on present projections. Forest lands will decline from a present area of 15.94 million hectares (39.4 million acres) to 15.90 million hectares (39.3 million acres) in 1980, to 15.7 million hectares (38.8 million acres) in 2000, and to 15.5 million hectares (38.4 million acres) in 2020. Forest lands cleared for agriculture will approximately equal abandoned agriculture and pasture lands revegetating to forest. Essentially all forest land use changes, 405 thousand hectares (1.0 million acres), will be to urban (44).

If the annual cut were to be maximized within the limitations of sustained yield management, approximately 243 thousand hectares (600 thousand acres) of forest lands will be harvested annually to the year 2020. This is probably an over-estimation, but approximately represents a maximum potential. This estimate is based on the projected demand to 2020 and assumes existing per acre volumes continuing for the duration. However, it is probable that future timber demands will encourage more efficient management of forest lands, particularly on small private forest tracts, thus either increasing total production or decreasing area cut annually. Approximately 30 percent of the area harvested annually will be under the supervision and/or guidance of a professional forester.

Approximately 344 thousand hectares per year (850 thousand acres) of grazed forest lands will be disturbed to the point of producing accelerated sediment yields. Forest land grazing will be eliminated on 7.9 thousand hectares (19.5 thousand acres) annually to the year 2020 (44). This type of disturbance may decline in the future with the further implementation of feed lots.

Forest urbanization will occur at a rate of 8.3 thousand hectares (20.5 thousand acres) annually until the year 2020(44). This represents a major impact on forest lands in terms of lost timber, wildlife habitat, recreation base land and water quality impairment.

Future forest land effects on the water quality of the Great Lakes will probably remain the same or be reduced. If funding for forest management is increased, substantial reductions in pollutants should result.

There will not be any significant area under intensive tree culture by 1980. There could be, however, by 2000 to 2020. Given the wide dispersal of the aspen cover type and the fairly long time interval between harvests (when maximum nutrient loss would occur), it seems unlikely that such management would be concentrated enough to produce measureable effects on water enrichment much beyond the confines of the particular forest stand. However, there may be a tendency to concentrate intensive management practices near wood-using mills. In this case, there may be a high enough proportion of selected small watersheds under intensive management to affect water nutrient concentrations over longer distances downstream. The effect on the water quality of the Great Lakes would depend on the location of these watersheds in the Basin. However, the effect is expected to be minimal.

3.9 Review of Institutional Arrangements to Control Forest Land Use

The most comprehensive legislation affecting forest activities is the 1971 amendments to the Federal Pollution Control Act, commonly referred to as the Water Bill (Public Law 92-500). The act has given the Administrator of the Environmental Protection Agency the responsibility to determine in each state the extent, nature, damages, appropriate control measures, and treatment costs of all the water polluting activities; including non-point source activities such as forestry. This is to be accomplished by coordinated research and inventories by federal and state agencies and other public and private organizations. The purpose of the act is to restore and maintain the chemical, physical, and biological quality of the nation's waters. The goals are to provide sufficient water quality for the protection and propogation of fish, shellfish, and wildlife, and for recreation in and on the water by 1983, and to eliminate all pollution discharges into navigable waters by 1985.

State governments are already passing erosion and sediment control laws. A model act has been published by the National Association of Conservation Districts and appears to be gaining in popularity. The act requires that before any land disturbing activity begins, an erosion and sediment control plan be submitted and be in conformance with set guidelines and standards. Extended authorities to administer the legislation would be given to the state agency with overall responsibility of water quality control and the Water Conservation Districts. Standards governing the installation and maintenance of control measures would be imposed on the forest landowner or operator.

States within the Great Lakes Basin are in the following stages of enacting erosion and sedimentation control legislation:

Laws have been enacted:

Michigan
Ohio
Pennsylvania

Laws have been drafted and introduced:

Illinois
Minnesota
New York

No action:

Indiana
Wisconsin

In conjunction with erosion and sedimentation controls, land use zoning, particularly floodplain zoning, is necessary. Such action would enhance and ensure the beneficial hydrologic effects of forest lands. Over time this should have a significant beneficial effect on water quality. At the present time not enough personnel nor funding is available to obtain adequate data to develop land use regulations, management techniques, and alternatives.

Regulations concerning forest activities and water enrichment from nutrient release are non-existent in the Basin, due to the lack of adequate information to develop regulations and determine the effectiveness of present management techniques and available alternatives.

When adequate information becomes available, it may be necessary to regulate harvesting, grazing, recreation, and prescribed burning.

Controls on pesticide use are very stringent, at least on federal and state forest lands. Before any pesticide project can commence on federal lands or where projects involve federal funds, an environmental impact statement must be made and submitted for review by the Environmental Protection Agency and the Council of Environmental Quality as required by Public Law 91-190 (National Environmental Policy Act of 1969). In addition, this law requires the strict adherence to the use and application directions stated on the label of pesticide containers.

The Federal Insecticide, Fungicide and Rodenticide Act, 1967, regulates the marketing of economic pesticides. Under this act no pesticide chemical may be legally shipped in interstate commerce for general use until it has been shown safe when used as directed and for the purpose claimed on the label. Under the authority of this act certain pesticides have recently been banned or put into a restricted use category due to their adverse environmental effects.

Where federal funds are not involved, pesticide use and application are subject to state regulation. All states in the Basin except Pennsylvania and Wisconsin have state legislation concerning use and application of pesticides and require a license or permit from the state. All of the states have enacted laws pertaining to the type of pesticides that can be used. Most states exempt the private landowner from use and application regulations when applying pesticides on his own land. An excellent review of state regulations can be found in the Digest of State Pesticide Use and Application Laws by the Environmental Protection Agency, 1973.

In terms of forestry, pesticide use regulations appear to be adequate. This opinion is based on the small quantity of pesticides used on forest lands in relation to the total use in other land use categories. In general, however, pesticide laws are ineffective in enforcing pesticide use restrictions on private ownerships. Inadequate funds and personnel severely limit the monitoring and enforcement of these laws. Another possible inadequacy of pesticide regulations is monitoring techniques. Pesticide levels are written for water only, and, therefore, only water samples are analyzed. Recently researchers have indicated the importance of sediments in assimulating pesticides. However, sediment samples are seldom analyzed for pesticide residues as a part of a monitoring program. Basinwide pesticide sediment monitoring should be implemented.

Section 4

SUMMARY OF RELEVANT ONGOING OR PROPOSED RESEARCH, DEMONSTRATION OR MONITORING PROGRAMS

4.1 Ongoing Research

4.1.1 Sediment

Forest erosion and sedimentation research in the Basin are virtually non-existent. However, similar research has been conducted in other areas of the country which has practical applications. The Forest Service, North Central Forest Experiment Station, in cooperation with the Michigan Department of Natural Resources is studying the effects of erosion and sedimentation, primarily streambank erosion, on fish and fish habitat.

Two Environmental Protection Agency control studies may have forestry implications. One study is to provide adequate information on the costs of retaining sediments on construction sites as opposed to correcting downstream damages. The other study, being completed by the National Association of Conservation Districts, is to explore nonpoint source erosion and its control. Forest activities such as grazing, harvesting, burning and dispersed recreation are considered nonpoint sources.

4.1.2 Nutrients and Pesticides

Monitoring of pesticide applications is done on projects involving federal lands. Extensive water quality monitoring is also being done in the Boundary Waters Canoe Area (Superior National Forest) and the Sylvania Recreation Area (Ottawa National Forest) in an attempt to assess the impacts of recreational use.

At the University of Minnesota, the effects of forest management systems on water quality and quantity are being evaluated. Of particular interest is the evaluation of harvesting and slash disposal on water quality and productivity.

Outside the Basin, North Central Forest Experiment Station researchers on the Marcell Experimental Forest, Minnesota, are analyzing the nutrient content of runoff waters from a forested bog-upland complex. In addition, the effects of lowland strip cutting and upland harvesting

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on water yield and quality are being evaluated.

4.1.3 Intensive Tree Culture

Intensive tree culture is being investigated by researchers of the North Central Forest Experiment Station, Forest Service, in Rhinelander, Wisconsin. The objectives are to develop the most efficient and economically feasible methods of producing maximum commercial fiber per acre.

In a University of Michigan project, an aspen stand has been clearcut to determine nutrient cycling and losses after harvesting.

Forest researchers at the Institute of Paper Chemistry, Appleton, Wisconsin, are testing the possibility of converting poorly stocked northern hardwood stands to stands of selected aspen clones.

North Central Forest Experiment Station researchers at Houghton, Michigan, are developing engineering systems for tree harvesting and a technique for bark removal from wood chips.

4.2 Proposed Research

The results of the following proposed research, if implemented, would aid in determining the effects of forest activities on water quality in the Great Lakes Basin. These studies have been proposed for investigations outside the Basin on the Marcell Experimental Forest, Minnesota, by the North Central Forest Experiment Station.

The objectives of the proposed studies are:

1. To determine the effects on water yield and quality of prescribed burning in black spruce bogs and upland sites.

2. To determine the effects of forest harvesting on water yield and quality. Techniques such as mechanized logging and full tree logging will be evaluated.

3. To evaluate the fate of herbicides in organic soils.

4. To evaluate the effect of forest fertilization on water quality and develop fertilization techniques that minimize water quality changes.

5. To investigate the route of waters flowing from uplands into and through peat bogs. This is necessary to develop an input-output balance of nutrients and the nutrient absorption capacity of various peatland materials and organic soils.

6. To determine the effect of upland mechanical site preparation on water quality.

Section 5

NATURE AND AVAILABILITY OF TECHNOLOGY TO COPE WITH POLLUTION PROBLEMS

5.1 Sediment

The forest activities of harvesting, grazing and urbanization account for almost all of the accelerated forest land sediment production.

5.1.1 Detection and Evaluation

The measurement of erosion and sedimentation, especially of suspended sediment loads, has been done by many federal, state and private agencies. Although procedures for measuring suspended sediment are well established, measurements of bed load and total sediment load are not common and are somewhat difficult to accomplish.

An estimate of erosion can be accomplished by applying the Universal Soil Loss equation. This equation takes into account annual rainfall intensity and energy, degree and length of slope, the natural erodability of the mineral soil, and the cover and management characteristics. At the present time, the sediment yield estimates by this approach are very subjective. Whenever sediment yield ratios are available, they should be used. A field procedure for utilizing the Universal Equation has been developed by Alfred Darrach, Northeastern Area, State and Private Forestry, U.S. Forest Service. The procedure may be found in the Forest Service Handbook, 3509.21NA - Forest Land Erosion and Sediment Evaluation (128).

Another method that provides an economical way to estimate forest land erosion and sediment rates takes into account coarse fragment and organic content of the soil, slope, ground cover, crown cover, rainfall, and soil texture, structure and permeability (122). If these variables were quantified for the Great Lakes Basin, soil loss in inches per year and an erosion hazard rating could be estimated. The greatest potential for economically evaluating forest land erosion and sedimentation lie in empirical formulas such as these.

5.1.2 Harvesting

When proper management is implemented in harvest operations, accelerated sediment production is minimal. The proper location, construction and maintenance of logging roads and skid trails is the focal point (78)(67)(53).

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Proper management starts at the planning stage. Planning can reduce logging and skid trail area by 40 percent (64). Planning will also ensure proper grades on access roads. A minimum grade of 3 percent is desirable for adequate drainage. Gradients should not exceed 10 percent except for occasional short sections where grades should be limited to 15-20 percent.

The importance of adequately drained logging roads cannot be overemphasized. Various control measures as culverts, broad based dips, outsloping, traffic control, seeding and water bars will provide adequate drainage (51)(64)(98)(128). Placement and spacing recommendations for control measures are easily found in research publications and in state and federal forestry agency handbooks.

Stream protection is as important as road drainage. Roads crossing both perennial and intermittent streams should use bridges or closed culverts. Researchers have concluded that a protective strip of undisturbed forest between harvested areas and streams help prevent excessive sedimentation (77)(66)(64)(51). The width of the protected strip varies with the steepness of the topography and soil types. A generally accepted formula for determing the width of a buffer strip between harvesting operations and a drainage is as follows:

$$\text{Width in feet} = (4)(\text{percent slope}) + 50 \text{ feet}$$

When harvesting does occur near a stream, only selection cuts should be made with skidding upslope away from the stream.

Providing the previous control measures and management procedures are implemented, minimal and certainly tolerable accelerated sedimentation should result.

5.1.3 Grazing

Accelerated erosion from forest land grazing is best controlled by reducing grazing intensity or eliminating it altogether. Grazing intensities should be reduced to the point where sufficient plant cover is retained to protect the soil so that erosion is kept at tolerable limits. If intensity cannot be reduced then the stands should be opened to sunlight and seeded with grasses. A good compromise is the elimination of grazing along streams and drainages and establishment of protective buffer strips. Buffer widths vary by slope, soils and grazing intensities. This is one of the most easily remedied sources of accelerated forest land sediment but in the past one of the hardest to implement. Regulatory legislation may be required for an effective control program.

5.1.4 Urbanization

Urban forestry has primarily been the preservation and maintenance of shade trees and metropolitan forests for recreation and aesthetics. In the future, urban forests should be considered in the planning, zoning and development or urban-suburban areas. The urbanization of forest lands should be done with a minimum of soil disturbance. An example would be cluster developments leaving large surroundings of relatively undisturbed forest. In the future forest lands could be strategically planted and utilized for their hydrologic benefits and filtration of urban runoff. This could have a significant effect on urban sedimentation and provide a high standard of environmental quality.

5.1.5 Burning

Procedures for minimizing accelerated sediment production from burned areas are similar to those for severely grazed areas. Activities in the area should be curtailed for at least one year. On sites where mineral soil has been exposed, seeding or planting of trees and/or grasses may be necessary. This is particularly necessary along streams and drainages. Additional drainage control measures may be needed along forest roads to handle increased overland flows in severe burns.

5.1.6 All Disturbances

In most types of forest disturbances, there are adequate control measures to reduce accelerated sediment yield rates to tolerable levels. There is a need, however, to determine which alternative activities and control measures have the most favorable cost-benefit ratios.

5.2 Nutrients

Nutrient losses have not been identified with forest activities in the Great Lakes Basin. Although there is an established technology to deal with erosion losses, a principal nutrient transport mechanism, no technology specific to nutrient losses has been developed.

5.3 Pesticides

Pesticide effects on the forest environment and water quality can best be controlled by the manner in which the pesticide is applied. Manufacturers' label instructions and precautions should be strictly followed as to use, target species, mixing, application rate, and safety. Label instructions are closely controlled during the registration process by the Environmental Protection Agency. Pesticide application should be made only during favorable weather conditions, paying particular attention to wind, rain, and turbulent air. Air temperature and relative humidity requirements vary by pesticide.

Adequate buffer strips should be maintained between the target area and surface waters. Monitoring should be done where surface water contamination may occur.

Section 6

NEED FOR NEW RESEARCH, DEMONSTRATION OR MONITORING PROGRAMS

Since very little research in forest activities and their associated effects on water quality has been done in the Basin, research concerning erosion, sedimentation, nutrient budgets and the fate of pesticides is needed. Once the effects, if any, have been analyzed, management techniques to minimize and correct any adverse impacts should be developed. In the interim the results and recommendations from published research outside the Basin (Lake States) should be utilized. In addition, the development of urban-environmental forest technology to provide economical and permanent solutions for reducing water pollutants from other land uses should be investigated.

6.1 Sedimentation

Research on forest activities and their effect on erosion and sedimentation would be best approached by coordinating sediment yield studies throughout the Basin. The importance of meteorological events, stormflow volumes and evaporation dictate the use of a paired watershed concept. Key variables are the extent and severity of the activity, location in the Basin and soils. For best results, studies should be in all forested watersheds.

To aid present field evaluations of forest land erosion and sedimentation, research is needed to localize and verify empirical formulas such as the Universal Soil Loss Equation for forest lands in the Great Lakes Basin. Coefficients for rainfall, soils and cover condition related to forest activities should be developed.

6.2 Nutrients

Research on nutrient budgets is needed. This research would be best conducted in watersheds with tight bedrock at shallow depths to facilitate water and nutrient discharge monitoring at one point in the stream. This would substantially increase the accuracy and reduce the cost as compared to studies conducted in an unconfined ground water system. Areas along the shore of Lake Superior might be suitable for such an approach. Specifically, nutrient release should be studied following forest harvesting, burning and site preparation with emphasis on the effects of intensive tree culture management techniques.

6.3 Pesticides

Pesticide monitoring as a standard procedure should be expanded to stream and lake sediments. Recent research has inferred that sediments play a major role in assimulating pesticides. These pollutants can enter the food chain through benthic organisms. If sediment and pesticides are significant, their effects on water quality and downstream environments should be researched.

6.4 Intensive Tree Culture

If forested areas are to be managed in the future for maximum fiber yield, then research on management techniques and their environmental impacts are needed. The degree of fertilization necessary to promote maximum yield and the amount permissible without substantial water contamination need to be determined. Investigations evaluating the effects of harvesting wood-plus-bark vs. on-site debarking on the nutrient budget and the magnitude of nutrient losses associated with site conversion are needed. The information is needed for development of methods for minimizing nutrient losses, if losses are excessive.

6.5 Forest Land Inventories

Inventories to determine the extent, location and severity of forest land disturbances are desirable. With new capabilities in high altitude remote sensing and computerized data retrieval, these inventories may become economical and accurate.

6.6 Gaps in Knowledge by 1980

Sufficient water quality data related to forest land activities in the Great Lakes will not be generated by 1980. This type of research requires a time period of 4 to 6 years and presently has not been initiated on many of these "problems". Furthermore, urban and agricultural lands with similar pollutants have been identified as greater contributors and have been given corresponding higher research priorities.

Section 7

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Land Use/Water Quality Relationships in the U. S. Great Lakes Basin
Task A: To assess problems, management of programs and research...
Category All - Recreation Land

EFFECTS OF RECREATION AND RECREATIONAL LAND AND WATER USE ON WATER QUALITY IN THE GREAT LAKES BASIN

prepared by
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Section 1

SUMMARY

1.1 Introduction

Recreational lands, recreational activities and recreation-associated activities within the Great Lakes Basin contribute a variety of pollutants to surface and groundwaters. Because of the diversity in the physical nature of recreational land, and the vast variety of recreational events and activities within the Basin, the pollution loads entering the waters are difficult to classify. Inputs of sediment, plant nutrients, heavy metals, oil and grease, pesticides and bacteria/viruses can all be associated with one or several recreational activities. Because of the multiplicity of factors involved, it is understandable that there is a dearth of reliable quantitative measurements of pollutant inputs from many recreational sources. Consequently, assessment of the overall effect of recreation and recreational land on Great Lakes water quality is restricted by this limitation.

Preliminary indications do, however, suggest that for the Great Lakes themselves, adverse effects on water quality arising from recreational use of land and water are generally minor or negligible. If problems arise, they are likely to be temporary and occur in strictly localized littoral vicinities. Acute or chronic difficulties are more likely to be encountered with smaller lakes, impoundments, or streams within the Basin.

A vast increase in recreational participation and in recreational land and water needs is anticipated within the next 50 years as consequences of population growth, greater affluence, relative increases in leisure time and improved accessibility of outdoor recreational areas. The current (1973) level of recreational participation in the Great Lakes Basin of approximately 700 million recreation days* is expected to expand by factors of 1.10, 1.23 and 1.95 for the target years 1976, 1980 and 2020. The development of new technologies may increase these factors by creating more leisure time and associated socio-economic benefits. New technologies may also create and popularize new types of recreational activity with presently unknown positive or negative environmental effects.

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* Recreation day = one person participating in outdoor recreation for all or most of one day.

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However, it appears that expansion of the minor pollution loads contributed to the Great Lakes by known recreation land use and recreational events can and probably will be circumvented. In fact, because of a variety of factors--such as the recognition of the origin, nature and extent of pollutant inputs, research and development efforts of state and federal government institutions and of industry, expanded use of educational programs, intelligent regulation of recreational activities and land and water use--it appears likely that the present level of pollution loads associated with recreation can be controlled.

1.2 Summary of Findings and Conclusions

1.2.1 Nature and Extent of Recreational Land

Broadly defined, recreational land accounts for approximately 54,804 km^2 (21,160 miles^2) and represents 18% of the total land mass of the Great Lakes Basin (305,000 km^2 ∿ 117,600 square miles). However, over 97% of this land composes primitive or natural environment areas, principally wilderness or forests with public access which have only minor impacts (2,108,252)[1] on the water quality of the Great Lakes.

Only about 2% (1,127 km^2 ∿ 435 square miles) of all recreational land in the Basin is made up of high density recreational land or general recreational areas, where concentrated use may lead to temporary, seasonal or localized pollution problems.

In addition to the land area, approximately 10,360 km^2 (4,000 sq.

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[1] Figures in parentheses refer to documents cited in the references at the end of this report (Section 7.1).

miles) of Great Lakes surface water and some 6,993 km^2 (2,700 sq. miles) of smaller lakes and many miles of rivers are available for water-based recreation within the Basin. Whereas some of the smaller "inland" lakes and rivers may stand in jeopardy of cultural eutrophication or of outright pollution as a result of recreational activities, the dilution factor precludes significant general impact on Great Lakes water quality from such activities.

1.2.2 Nature of Recreation-related Pollutants

There are numerous types of pollutants that result from recreational use of land and water. For instance, sediment and detritus result from soil erosion and runoff from parks, from land-based activities, including skiing, snowmobiling, off-road vehicle use and from marina construction and dredging, summer home and resort developments and road and trail construction. Plant nutrient inputs--especially nitrogen and phosphorus--arise from septic tank systems in summer homes, ski resorts, campgrounds, etc., from fertilizer applications to golf greens, from leisure boat sewage and so on. Heavy metal enrichment can be derived from outboard, marine and snowmobile engines using leaded fuels; leadshot from duck and goosehunting; mercurial fungicides applied to golf greens, etc. Direct inputs of oil and toxic fumes (hydrocarbons, carbon monoxide, nitrogen oxides) occur from marine engines and indirect influx from automobiles, snowmobiles and other recreational vehicles. Lastly, biological pollutants (bacteria and virus) are derived from boat sewage, septic tank effluent, groundwater from stables and swimming and bathing activities.

Some of these pollutants are deposited directly in the lakes and tributary rivers, e.g. marine engine fuel spills and exhaust and boat sewage, others are carried in by surface waters or runoff, e.g. fertilizer, soil and detritus, while others enter through the groundwater aquifer, e.g. nitrates from septic tank effluent.

It is important to consider the pollution loads entering all the waters in the Basin, not only the Great Lakes themselves, for two reasons. Inland lakes and rivers serve as tributaries to the Great Lakes, so that that there may be some carryover of pollutants, but more importantly, any deterioration in recreational water quality in rivers and smaller lakes in the Basin places a greater demand and stress on the Great Lakes for recreational purposes.

1.2.3 Extent of Pollution

In actual fact, only in a few instances have any of the above pollutants been clearly identified as having significant or lasting effect on water quality. Moreover, in the few isolated cases where quantitative measurements have been made, the studies have been carried out either on relatively small, shallow lakes or ponds or in tiny experimental impoundments, sometimes with exaggerated inputs, so that magnified effects could become observable in acceptable time-spans. In general, the results of these investigations have revealed impacts of a magnitude such that only smaller bodies of water under analogous circumstances are likely to be adversely affected. The manifold dilution of the realistic pollution loads entering the Great Lakes or even the majority of the myriad of small recreational lakes in the Basin would render most pollutants innocuous.

Although the magnitude of the pollution loads reaching natural waters from recreational areas and recreational activities have seldom or never been measured accurately, definite inputs from a variety of sources have always been suspected. In fact, excessively high levels of some pollutants emanating from recreational sources have been recognized transiently in restricted localities. For example, when significant amounts of boat sewage have been dumped under adverse conditions in confined areas, bacterial counts in excess of safe levels for swimming or waterskiing have been measured. Consequently, justly or unjustly,

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indictments or accusations have often been leveled at individual recreational groups. Often these have been emotional charges from parties adverse to a particular form of recreation. However regardless of these issues, and of whether the magnitude of pollution loads be known or not, recreational lands and recreational activities can and do have direct and indirect effects on water quality. These range at present from insignificantly low "background" levels associated with natural processes in wilderness recreational areas to sizable inputs of N, P and sediment from concentrated, highly developed recreational areas which do not have adequate sewage treatment facilities. Summary appraisals of the overall importance of different types of recreational lands and recreational activities on water quality for the Great Lakes and other minor lakes in the Basin are given in Tables 1 and 2.

1.2.4 Control of Pollution

Fortunately, many of the phenomena associated with the potential inputs mentioned above and identified in the tables can be easily controlled or regulated so that even acute temporary problems in localized areas can be avoided. From the legal standpoint, a variety of federal and state laws, and local ordinances will help prevent abuses and ensure that future developments comply with recognized progressive practices. Pertinent legislation includes such measures as the requirement of environmental impact statements for new developments, recreational vehicle licensing, and compliance with land use zoning laws, water quality standards, engine emission standards, boat sewage disposal regulations and plumbing and health codes. In addition, expanded implementation of recent technological developments will produce further benefits. These include improved septic systems, inboard marine sewage treatment systems, marine engines with crankcase drainage recycling, unleaded fuels and non-lead grapeshot for wildfowl hunters. In a supportive role further improvements are expected from new regulatory and educational programs and from engineering developments, for example, improved designs for

TABLE 1

Projected impact of recreation land by land class, including estimates of average current inputs of N, P and sediment

<table>
<tr><th rowspan="2">Class*</th><th rowspan="2">Nature of Land/Area In Acres and Hectares (1970 figures)</th><th colspan="4">U.S. Great Lakes</th><th colspan="4">Inland Lakes</th></tr>
<tr><th>1973</th><th>1976</th><th>1980</th><th>2020</th><th>1973</th><th>1976</th><th>1980</th><th>2020</th></tr>
<tr><td rowspan="4">I</td><td rowspan="4">High density recreation areas
53,861 A=21,806 Ha</td><td>2-3**</td><td>3-4</td><td>4</td><td>4</td><td>1-3</td><td>2-3</td><td>3</td><td>3-4</td></tr>
<tr><td colspan="4"></td><td>N</td><td>P</td><td>sediment</td><td></td></tr>
<tr><td colspan="3" rowspan="2">1973 loads</td><td>lb/A/year</td><td>150-300</td><td>5-10</td><td>2,000-9,000</td><td></td></tr>
<tr><td>kg/Ha/year</td><td>168-336</td><td>6-11</td><td>2,240-10,080</td><td></td></tr>
<tr><td rowspan="4">II</td><td rowspan="4">General outdoor recreation area
218,355 A=88,403 Ha</td><td>3</td><td>3</td><td>3</td><td>3</td><td>3</td><td>3</td><td>3</td><td>3</td></tr>
<tr><td colspan="4"></td><td>N</td><td>P</td><td>sediment</td><td></td></tr>
<tr><td colspan="3" rowspan="2">1973 loads</td><td>lb/A/year</td><td>25-50</td><td>1-2</td><td>1,000-2,000</td><td></td></tr>
<tr><td>kg/Ha/year</td><td>28-56</td><td>1-2</td><td>1,120-2,240</td><td></td></tr>
<tr><td rowspan="4">III</td><td rowspan="4">Natural environment areas
12,955,730 A=5,245,235 Ha</td><td>3</td><td>3</td><td>3</td><td>3</td><td>3</td><td>3</td><td>3</td><td>3</td></tr>
<tr><td colspan="4"></td><td>N</td><td>P</td><td>sediment</td><td></td></tr>
<tr><td colspan="3" rowspan="2">1973 loads</td><td>lb/A/year</td><td>0.9-3.6</td><td>.02-0.2</td><td>200-320</td><td></td></tr>
<tr><td>kg/Ha/year</td><td>1-4</td><td>.02-0.2</td><td>225-360</td><td></td></tr>
<tr><td rowspan="4">IV</td><td rowspan="4">Outstanding natural areas
436,710 A=176,806 Ha</td><td>3</td><td>3</td><td>3</td><td>3</td><td>3</td><td>3</td><td>3</td><td>3</td></tr>
<tr><td colspan="4"></td><td>N</td><td>P</td><td>sediment</td><td></td></tr>
<tr><td colspan="3" rowspan="2">1973 loads</td><td>lb/A/year</td><td>0.9-3.6</td><td>.02-0.2</td><td>200-320</td><td></td></tr>
<tr><td>kg/Ha/year</td><td>1-4</td><td>.02-0.2</td><td>225-360</td><td></td></tr>
<tr><td rowspan="4">V</td><td rowspan="4">Primitive areas
1,193,674 A=483,269 Ha</td><td>3</td><td>3</td><td>3</td><td>3</td><td>3</td><td>3</td><td>3</td><td>3</td></tr>
<tr><td colspan="4"></td><td>N</td><td>P</td><td>sediment</td><td></td></tr>
<tr><td colspan="3" rowspan="2">1973 loads</td><td>lb/A/year</td><td>0.9-1.8</td><td>0.02-0.1</td><td>200-320</td><td></td></tr>
<tr><td>kg/Ha/year</td><td>1-2</td><td>0.02-0.1</td><td>225-360</td><td></td></tr>
<tr><td rowspan="2">VI</td><td rowspan="2">Historic and cultural sites
4,327 A=1752 Ha</td><td>3/4</td><td>3/4</td><td>4</td><td>5</td><td>4</td><td>4</td><td>4</td><td>5</td></tr>
<tr><td colspan="8">Greatly accelerated erosion possible at individual sites.</td></tr>
</table>

*ORRRC Classification system

**(1) Serious
(2) Moderate
(3) Low
(4) Negligible
(5) Not detectable

Note: Class I and II lands are intensively developed for recreation and provide most of the opportunities for recreational activities. Between 30 and 70% of the total land surface of Class I is developed for recreation, with an average development of 50%. The development of Class II lands averages 15% with a range of development from 5 to 30% (124).

Throughout the text, A equals acres, and Ha equals hectares.

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TABLE 2

Projected Impact of Recreational Activities on Water Quality in the Great Lakes and Inland Lakes within the Great Lakes Basin*

Recreation Activity	Nature of Pollutants	U.S. Great Lakes 1973	1976	1980	2020	Inland Lakes 1973	1976	1980	2020
Driving for pleasure	Lead, nitrogen oxides, hydrocarbons, CO; erosion from road construction, dirt roads, unsurfaced parking lots	2-3(b)	3(b)	4(b)	4(b)	2-3(b)	3(b)	4(b)	4(b)
Walking for pleasure	Accelerated streamland erosion	4(a)	4(a)	4(b)	4(b)	3(a)	4(a)	4(b)	4(b)
Playing outdoor games or sports	N, P, Hg from golfcourses, playing fields	4(a)	4(a)	4(b)	4(b)	1-3(c)	2-3(c)	3(b)	3(b)
Sightseeing	Accelerated erosion from parking lots, near outlooks, footpaths, etc.	2-3(a)	2-3(a)	3-4(b)	4(b)	2-3(c)	2-3(c)	3-4(b)	4(b)
Bathing, swimming	Resuspension of bottom sediments, sand deposition on swimming beaches; bacteria, virus; N, P	3-4(c)	3-4(c)	3-4(d)	3-4(d)	3(c)	3(c)	3-4(d)	3-4(d)
Bicycling	Accelerated erosion from bike trail construction, unsurfaced trails	4-5(b)	4-5(b)	4-5(b)	4-5(b)	4-5(b'	4-5(b)	4-5(b)	4-5(b)
Picnicking	Litter	5(b)	5(b)	5(b)	5(b)	5(b)	5(b)	5(b)	5(b)
Attending outdoor sports events	Litter, accelerated erosion from unsurfaced parking lots	4-5(b)	4-5(b)	4-5(b)	4-5(b)	4-5(b)	4-5(b)	4-5(b)	4-5(b)
Fishing	Litter, oar, marine engine exhaust; fish hatchery wastes, fishkill from overstocking; streambank and lakeshore erosion; resuspension of bottom sediments; antifreeze	3-4(a)	3-4(a)	3-4(b)	3-4(b)	3-4(c)	3-4(c)	3-4(b)	3-4(b)
Nature walks	Accelerated erosion from trail construction and unstable areas, streambanks; litter	4-5(b)	4-5(b)	4-5(b)	4-5(b)	4-5(b)	4-5(b)	4-5(b)	4-5(b)
Power boating	Lead, nitrogen oxides, hydrocarbons, CO; human waste from onboard toilets; litter, erosion from wave action on river banks and shorelines	3-4(a)	4(a)	4(b)	4(b)	3-4(c)	3-4(c)	4(b)	4(b)
Hunting	Litter; lead from shot; accelerated erosion in unstable areas; gamefarm wastes; sewage wastes	3-4(a)	3-4(a)	4(b)	4(b)	3(c)	3(c)	3-4(b)	3-4(b)
Ice skating	None	5(b)	5(b)	5(b)	5(b)	5(b)	5(b)	5(b)	5(b)
Horseback riding	Stable wastes, accelerated erosion from bridle paths, trails	4(a)	4(a)	4(b)	4(b)	3-4(c)	3-4(c)	3-4(b)	3-4(b)
Camping, summer homes	Litter, sewage, erosion from campsites, home construction	4(a)	4(a)	4(b)	4(b)	3-4(c)	3-4(c)	3-4(b)	3-4(b)
Sledding and tobogganing	Erosion from trails, sled runs	5(b)	5(b)	5(b)	5(b)	5(b)	5(b)	5(b)	5(b)
Attending outdoor artistic events	Litter, sewage erosion	4-5(a)	4-5(b)	4-5(b)	4-5(b)	4-5(a)	4-5(b)	4-5(b)	4-5(b)
Hiking	Erosion; litter	5(b)	5(b)	5(b)	5(b)	5(b)	5(b)	5(b)	5(b)
Water skiing	Same as power boating	4(a)	4(a)	4(b)	4(b)	3-4(c)	4(c)	4(b)	4(b)
Canoeing	Litter; bank erosion at portage areas	5(a)	5(b)	5(b)	5(b)	4-5(a)	4-5(b)	4-5(b)	4-5(b)
Sailing	Sewage wastes	5(a)	5(a)	5(b)	5(b)	4-5(a)	5(a)	5(b)	5(b)
Snow skiing	Accelerated erosion at new developments; sewage at ski resorts	4(a)	4(a)	4(b)	4(b)	3-4(c)	3-4(c)	3-4(b)	3-4(b)
Snowmobiles	Lead, N oxides, hydrocarbons, CO; accelerated erosion from trails, destruction of vegetative cover; litter	4(b)	4(b)	4(b)	4(b)	3-4(b)	3-4(b)	3-4(b)	3-4(b)
Off-road recreation vehicles	Litter; engine exhaust; accelerated erosion from soil compaction; destruction of vegetative cover	5(b)	5(b)	5(b)	5(b)	4(b)	4(b)	4(b)	4(b)
Rock climbing	Erosion from unstable areas	5(b)	5(b)	5(b)	5(b)	5(b)	5(b)	5(b)	5(b)

* (1) Serious (a) Unknown)
(2) Moderate (b) Suspected)
(3) Low (c) Known) When known, or derivable estimates for pollution loads are discussed
(4) Negligible (d) Inevitable) in the text.
(5) Not detectable)

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lake-front developments, resort motels, ski lodges, summer homes, parking lots, scenic walks, snowmobile trails, etc. Each of these topics is discussed in detail in the appropriate context in this report. Overall, the situation appears to be quite healthy and promises to improve. The expected diminution in the "seriousness" of the impact of the various recreational land classes and recreational activities on water quality in the Great Lakes and the inland lakes of the Basin are reflected qualitatively in Tables 1 and 2 for the target years 1976, 1980 and 2020.

1.2.5 Question of Need for New Studies

Several recent and currently ongoing studies of the recreational vectors suspected to be most pernicious toward water quality, viz. power boating and septic tank effluent from unsewered recreational homes, campsites, etc., have revealed that these appear to be relatively non-polluting compared to either point sources or other diffuse sources associated with other land uses (see Table 3). Consequently an extensive research program on the impact of recreation on water quality seems unwarranted; however, a limited number of smaller, highly specialized studies to eliminate gaps in present knowledge may be justified.

Some ongoing studies are expected to provide pertinent information on and solutions to a few of the problems that now exist. Findings of other earlier studies which have not yet been extensively applied form the basis of some recommendations given below.

1.2.6 Nature of Potential New Studies

1.2.6.1 Research and Development

There are a few areas where collection of basic information or data might be helpful to decide whether some unknown hazards exist. For example, some further research on human health hazards associated with transfer of bacteria and virus during swimming seems justified. Examination of carcinogenic compounds (polynuclear hydrocarbons, nitrosophenols,

Table 3. Ratios by source of nitrogen and phosphorus entering surface waters in Wisconsin (after 137)*

Source	N	P
	% total	
Municipal treatment facilities	24.5	55.7
Private sewage	5.9	2.2
Industrial wastes	1.8	0.8
Rural sources		
manured cropland	10.6	24.6
forests	0.5	0.3
pasture and woodlots	0.7	2.9
ground water	42.0	2.3
Urban runoff	5.5	10.0
Precipitation on surface water	8.5	1.2
Total	100.0	100.0

* Table does not include contributions from aquatic nitrogen fixation, waterfowl excreta, chemical deicers, and wetland drainage.

chloramines) in waters receiving internal combustion engine exhaust or chlorinated sewage wastes is perhaps just as important. Precise measurements of actual losses of nutrients and sediment from well-defined, high intensity recreation sites could be made to derive models for improved management of such areas. For example, determinations of water quality parameters for seepage from septic systems in lakeside parks and derivation of soil erosion using the universal soil loss equation could indicate whether new guidelines are needed for design of such facilities. Measurement of actual peak soil losses associated for such high density recreational land use as snowmobile racing meets, horse shows, outdoor skating rinks, etc. would indicate whether these losses are serious. With this information sound practices in organization of such events to avoid soil losses could be recommended. Analogously, water quality measurements associated with high density water use, e.g. regattas, powerboat racing, waterskiing competitions would be indicative of serious short-term impacts.

1.2.6.2 Demonstration Projects

There are several areas in which demonstration projects could prove of benefit in establishing the value of new practices based on some recent findings or developments. A demonstration project could be used to show that catchment ponds may be used on golf courses to trap the high loads of fertilizer nutrients, mercurial fungicides, turfgrass thatch, etc. that may occur in runoff and thus prevent fouling of waterways and lakes. These ponds would act as natural "treatment" facilities while benefiting the activity by improving the aesthetic appearance of the course and providing additional sporting "water" hazards for the players.

Similarly, it may be possible to demonstrate on test sites that individual waste treatment systems are capable of dealing with peak loads for winter and summer resorts regardless of the types of soil and bedrock in the resort areas. Demonstration projects could be set

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up to show model methods for disposal or treatment of pleasure boat sewage at onshore facilities or for handling toilet wastes and litter at large recreational events (open-air rock concerts, fairs, etc.). Further projects could be used to demonstrate methods of constructing recreational facilities, parking lots, etc. on problem soils, e.g. red clays, using measures to stabilize shorelines and prevent excessive erosion.

1.2.6.3 Expanded Water Quality Monitoring Programs

Current listings of water quality monitoring programs and sites indicate that there may be some deficiencies with regard to the number of recreation-related monitoring programs, the frequency of sampling and the types of pollutants examined. Closer examination of sediment from high-density recreational lands and of the bacterial and nutrient contents of ground water near large unsewered recreational facilities should be conducted. Recreational waters should be monitored at times of peak use rather than at regular intervals.

1.3 Recommendations

1.3.1 Funding of New Studies

Since many areas of concern overlap with research interests of other organizations and agencies, some of the research, demonstration and monitoring programs suggested should be supported as cooperative projects. Public health problems should be examined in collaboration with state or federal health programs or organizations. Demonstration projects could involve collaboration with interested industries, recreational groups, or state or commercial land development programs. Expanded water quality monitoring should be performed in collaboration with state and federal organizations already conducting measurements in the Basin.

1.3.2 Control and Regulation

Beneficial changes in current practices could be introduced through new controls or regulations without causing unnecessary hardship to recreation business or recreation participants. Some of these changes would undoubtedly be welcomed and supported by the parties supplying or receiving services. Examples of some controls are the following:

First, marinas should be limited to offer only unleaded fuels for sale for powerboating. High quality unleaded gasoline is available at competitive prices and the compression ratios in typical outboard engines do no require high anti-knock fuels.

Second, all riding horses should be registered. This would benefit owners by helping to trace stolen animals and to pinpoint origins of outbreaks of disease. At the same time it would give accurate counts of the density and distribution of the animals and indicate whether measures would have to be recommended for disposal of their wastes.

Third, deadlines should be set for installation of adequate flush toilet facilities and septic disposal systems in both public and private recreational areas, campgrounds, ski lodges and the like. Such facilities would make the resorts more attractive to recreationers and simultaneously reduce the N,P, BOD, COD and bacterial loads entering some lakes and streams.

Fourth, depending upon future market expansion special licensing for off-road use of all terrain vehicles, such as minibikes, four-wheel drive vehicles, etc. may become necessary as well as trail regulations.

Fifth, guidelines should be established for the construction of lakeside recreational developments. These should define safeguard that must be taken to insure that excessive erosion does not occur during construction and prescribe the extent and nature of "buffer zones" separating buildings and their sewage treatment facilities from lakeshores.

Implementation of these recommendations should be made the concern of the states in the Basin, in collaboration with federal agencies. Where practical, state and local governments should assume the responsibility for enforcing and monitoring the disposal of boat sewage and for providing

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adequate pumpout and treatment facilities at small craft marinas. Since national supervision of this activity only recently became the responsibility of the Coast Guard, U.S. Department of Transportation, this agency has concentrated primarily on controlling discharges from commercial shipping in large harbors.

All of the states in the Basin have laws prohibiting overboard discharge of treated or untreated sewage from vessels of any size but current enforcement is unrealistic because of the lack of suitable on-board retention/treatment sanitation devices for small craft and the need for more onshore pumpout and treatment facilities. The number and distribution of the small craft fleet and marinas precludes the possibility of efficient supervision at present by the Coast Guard. State supervision could provide for rapid abatement of immediate pollution loads in many areas.

The no-discharge sewage law should be extended to cover sanitation requirements for ice fishing "bob houses" and shacks.

1.3.3 Policy Changes

Bicycling is an activity which provides recreational enjoyment and serves as a useful non-polluting form of transportation. There is at present a serious lack of bicycle paths and trails in the Basin, both in urban and rural localities. The 1970 number of bicycling recreationists (ca. 15,100,000 days/year) was projected to increase 20% by 1980 and more than double by 2020. Less than half of the requisite trails and paths were available in 1970 and the unsatisfied requirement is expected to rise to 88% by 2020. However, shortages of gasoline and concurrent price increases may enhance the popularity of bicycling, while decreasing expected expansions in automobile, powerboat, snowmobile and other powered vehicle use. It would therefore seem appropriate that some federal funds earmarked for highway construction should be diverted for construction of bicycle paths. Some promoters of bicycling suggest that portions of state vehicle licensing fees could also be justifiably used for this purpose, since reduction of bicycle traffic on general roads and highways would benefit motorists. Appropriate changes in current legislation would be necessary to provide for the reallocation of funds. Stretches of unused railroad tracts make ideal sites for new bicycle trails: railroad beds have invariably been well stabilized and carefully graded and contoured to avoid steep inclines. Many disused rural lines have been converted to bicycle trails in eastern states.

1.3.4 Educational Programs

The states should initiate comprehensive programs for promulgating the importance of good antipollution practices during recreational activities and for explaining environmental aspects of laws governing recreational activities. Statewide tests similar to the automobile driver examination afford a mechanism to insure that the user public is prepared to undertake certain activities. Informational brochures should be distributed with fishing, hunting, boating and snowmobile licenses and should also accompany replies to any request for brochures on sites for camping, skiing and other recreational activities. State maps should be prepared to describe the location of minibike, horseriding, skiing, sledding and snowmobile trails, boat-sewage disposal points, campgrounds with flush toilets etc. as aids to environmentally concerned recreationers.

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Section 2

SUPPORTING MATERIAL

2.1 Introduction

2.1.1 Background

The use of land and water resources for rest, relaxation and recuperation dates back almost as long as recorded history. Like many other pursuits, recreational use of land and water was at first principally reserved for the privileged classes. Extremes of this were visible in the monarchical pleasure domes and hanging gardens of the early eastern civilizations. Enlightened Roman civilization transiently extended the use of recreational facilities to a larger mass of its citizens through the medium of the circus and the public baths. The retrogression that occurred in the age of feudalism continued even through the Golden Age of the Renaissance, when enjoyment of the hunt and the pleasure gardens of the European nobility remained the exclusive right of royalty and peerdom.

The struggle for democracy that progressed through the early settlement of North America and the American Revolution witnessed a parallel democratization of land and water use. The abundant virgin resources of America's lands, forests and waters were available to one and all who ventured to settle there, regardless of rank, station or heritage. The availabily of land and water for public use has been wisely maintained ever since the early formative years of the Nation. The federal parks system was initiated in 1872, when Yellowstone became the first of the 33 national parks in the U.S. Since 1900, national forests, federal reservoirs, national monuments and other federal developments have provided for increasing amounts of outdoor recreational opportunities. Parallel development of state and county parks and forest systems has greatly supplemented these facilities. Widespread participation in the use of public lands and water for recreation began in the 1930's when the combination of mass production of automobiles and new highway construction in the aftermath of the Great Depression opened inaccessible areas to mass use. Except for a lull during the Second World War years, mass use of public recreation areas has continued to grow at a rapid rate (Fig. 1).

In 1970, there were 561,735 Ha (1,387,000 A) of national parks and wilderness and 218,700 Ha (540,000 A) of state and county parks in the Great Lakes Basin. In addition some 1,053,000 Ha (2,600,000 A) of Great Lakes surface waters and 688,500 Ha (1,700,000 A) of inland lake water surface were available for recreational purposes. However, it has been estimated that these resources were able to satisfy only 81% of the needs of the Basin's 1970 population of 29,013,200 for land-based water-oriented recreational activities (124).

The reason for this shortfall is the non-uniform distribution of population and recreational resources. Some 83% of the Basin's population (approx. 24,000,000 persons) live in metropolitan areas. As a consequence, recreational resources in metropolitan areas are being used to capacity or are overtaxed, whereas remoter resources receive low density use. Private shoreline development along the Great Lakes and on inland lakes and rivers has made large areas unavailable for recreational use by the general public. This situation is especially true in or near metropolitan areas. Moreover, municipalities, residences, cottages and industry have introduced waste loads into waters that have rendered them unfit for some forms of recreation, e.g. bathing, again primarily near urban areas. If not controlled, these conditions could be intensified.

Future total requirements for outdoor recreation in the Great Lakes Basin are expected to rise faster than population growth (see Fig. 2). The 1970 population of the Basin (29,013,200) is expected to grow by 84% to 53,496,300 by 2020, but the recreational demand is expected to expand 193% from the 1970 level of 637 million recreation days to about 1.9 billion recreation days in 2020. The accelerated rate is supported by predicted decreases in the average workweek, increases in per capita income, improved vacation and holiday schedules, increases in expendable

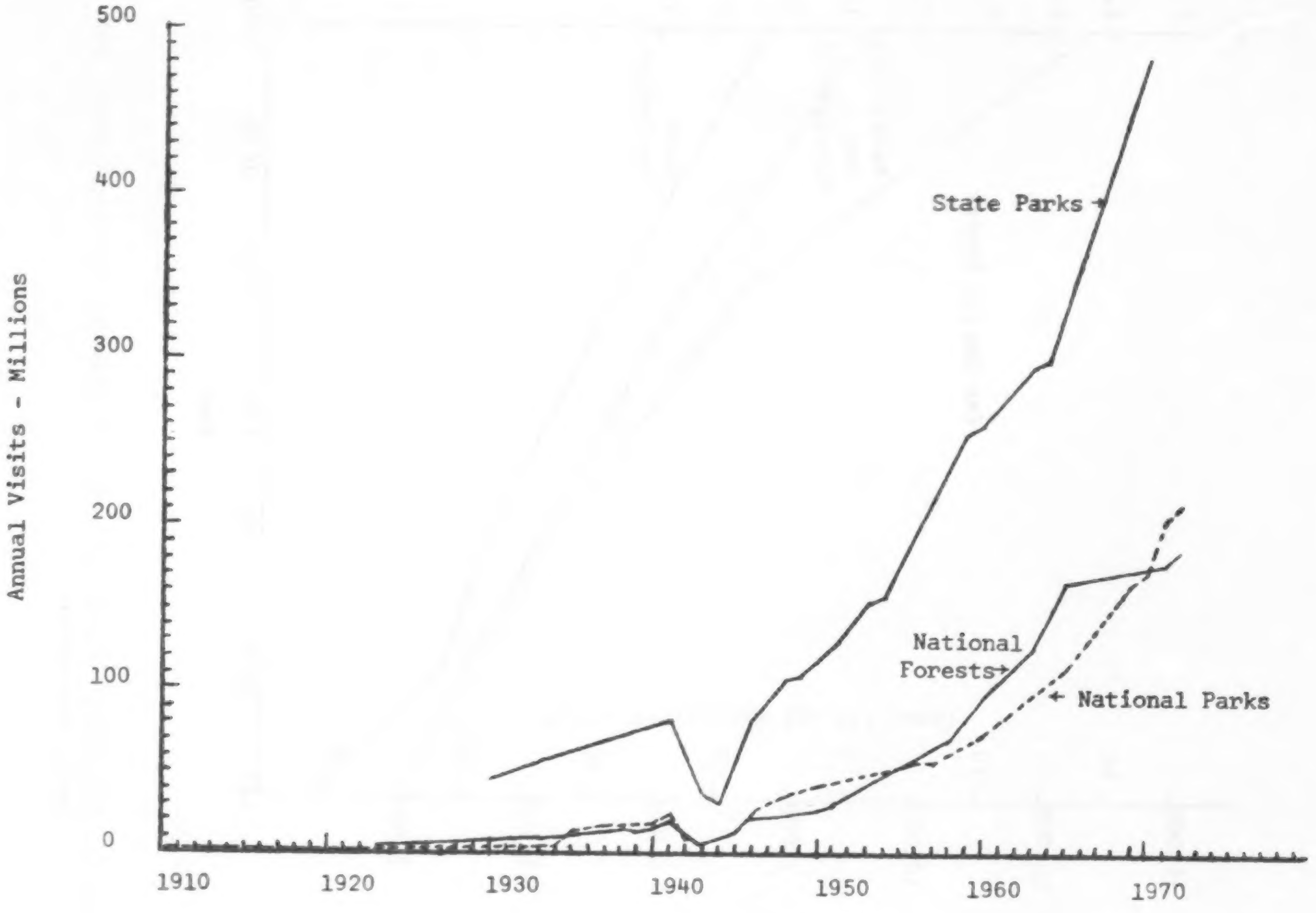

Figure 1. Nationwide participation in outdoor recreation in state and federal lands. (after 61,247,248)

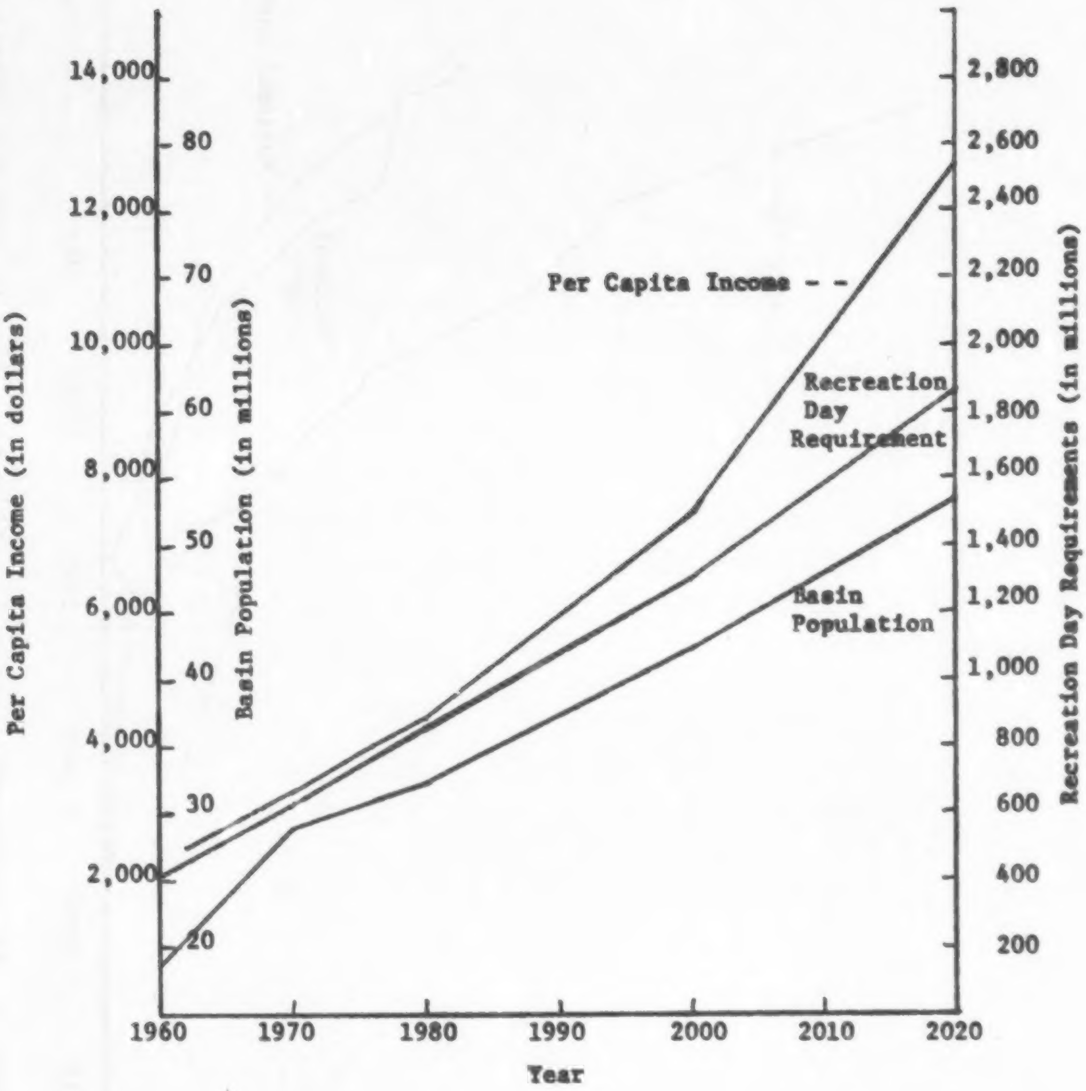

Figure 2. Per capita income and total recreation day requirement and basin population.

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income, increases in paid vacations and holidays and improved accessibility of recreational areas.

The bulk of the 1970 demand (76% or 486,000,000 recreation days) arose in urban areas and it is unlikely that this proportion will diminish. Consequently the 35% shortfall for all types of recreational opportunities in 1970 is expected to increase to 45% in 1980 and 72% in 2020. The shortfall for land-based water-oriented recreation is also expected to reach 72% by 2020 (124).

Even in the past, the disparity between recreation supply and demand has aroused concern for the need to keep recreational lands and water at a quality level fit for extensive use. Great efforts and expense have been invested to ensure that the quality of recreational waters is not impaired by influx of wastes from urban, industrial or commercial sources. However, recently people have begun to realize that intense land or water use by recreationers themselves might provoke environmental impacts that would detract from water quality.

An attempt has been made to review existing knowledge on the environmental consequences of recreation activities and to relate known and expected recreation land and water use and recreational participation to the types and amounts of pollutants likely to affect the water quality of the Great Lakes and of minor lakes in the Great Lakes Basin.

2.2 Scope of Study

2.2.1 Sources of Data

During the course of this review, both primary and secondary sources of data were consulted. Initial searches were made in bibliographies, abstracts and computer literature records to identify specific sources of information. Recourse was then taken to published scientific and technical papers and reports, books and texts and symposium proceedings. Furthermore, agencies and individuals were contacted directly to obtain information not readily found in the literature.

To obtain information on current studies and activities it was necessary to consult indices and catalogs of ongoing research and consult active researchers by correspondence, questionnaires or telephone interviews. Details of the principal information sources examined are given below in Section 2.2.3.

2.2.2 Time Frame

Although extensive investigations have been made on water quality for recreational use and the manner by which water quality may be impaired by point sources of pollution, few studies have been conducted on the effects of recreational activities themselves on water quality. Statistics of recreation participation and demands have been collected since the 1930's and for some forms of activity, e.g. boating, even earlier data are available. Information of past and present demands have been collected by states (e.g. 35, 71), lake basins (62-66) and by drainage basin regions (61, 124). Tabulations have generally been made by counties. At the national level information is now collected in computerized form by the U.S. Department of Interior's Bureau of Outdoor Recreation. However, it is only in the past 15 to 20 years that serious consideration has been given to the possible adverse environmental effects of recreation. Furthermore, only in the past 5 to 7 years have objective studies aimed at acquiring reliable quantitative data been conducted. Some types of recreational activity have only been initiated or popularized in this 5 to 7 year span and sound statistical data and environmental impact measurements for these activities are still lacking. To ensure thorough coverage of available information, bibliographic services were consulted, abstract searches were conducted by means of computerized systems and supplemented by manual searches of abstract journals as far back as 1950. Beyond this date, no pertinent keywords relating to wastes or by-products generated by recreational activities were found, except for

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references to specific indirectly-related topics such as septic tanks.

2.3 Study Procedure

2.3.1 Approach

The study was conducted using the personnel and resources of the University of Wisconsin Water Resources Center and the University of Wisconsin Libraries System. Computer searches were conducted through the University of Wisconsin Water Resources Information Program which had access to the Federal Water Resources Scientific Information Center Abstracts and the Chemical Abstracts systems. Abstract journals, documents, scientific journals and books were acquired from the Water Resources Center Reference Room, Memorial Library, Medical Library, Steenbock Agricultural and Life Sciences Library, Engineering Library of the University of Wisconsin-Madison and the City of Madison Public Library. Copies of pertinent materials were procured or purchased. Locally unavailable materials were obtained through interlibrary loans.

2.3.2 Interview with Research Personnel and Organizations

An intensive search was conducted to identify recent and ongoing research pertinent to the subject area. In addition to project descriptions the names and addresses of the investigators were selected from the CAIN, SIE, CRIS, NTIS and WRSIC computerized abstract services, and the Water Resources (255) and Environmental Protection Research Catalogs (256).

Over one hundred requests were sent to these scientists asking for published and unpublished information relative to the review. Unfortunately, nearly 10% of the mailing addresses for the investigators were inadequate and only 10% of the investigators responded to the request within the short time of the study.

Because of the lack of a rapid response, an intensive interview campaign was conducted by personal visits or by telephone. In most cases, some information was obtained, and it was typical of those interviewed to send written information as a follow-up to our conversations.

Government, industry and recreational agencies and organizations contacted during the review include: U.S. Environmental Protection Agency, USDI Bureau of Outdoor Recreation, USDI Geological Survey, USDA Soil Conservation Service, USDA Forest Service, USDI Bureau of Sport Fisheries and Wildlife, Upper Great Lakes Regional Commission, National Recreation and Park Association, National Parks Service, National Parks and Conservation Association, National Association of County Park Recreation Officials, Green Section Service, U.S. Golf Association, National Quarter Horse Association, American Horse Council, Wisconsin Horse Council, National Association of Boat and Engine Manufacturers, Boating Industry Association, Outboard Marine Corporation, Midwest Marina Association, International Snowmobile Industry Association, Snow Goer Magazine, Sports Afield, Sports Illustrated, Field and Stream, Recreation Vehicle Institute, U.S. Ski Association, National Ski Areas Association, Midwest Ski Areas Association, Central Ski Areas Association, Vermont Ski Areas Association,American Camping Association, National Rifle Association, Winchester Western Arms, Wisconsin Technical Waterfowl Committee, State of Wisconsin Dept. of Natural Resources, State of Michigan Dept. of Natural Resources, Sea Grant Program, Great Lakes Water Quality Board of Illinois, U.S. Army Corps of Engineers, University of Wisconsin-Madison Recreation Resources Center, South East Wisconsin Regional Planning Commission, Milwaukee County Parks Department, Milwaukee Sewage Commission, and Milwaukee County Board of Health.*

2.3.3 Sources of Literature Reviewed

Computer printouts of stored information were obtained from the following (data base in parentheses): Smithsonian Scientific Information Exchange (ongoing research), Water Resources Scientific Information

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* The assistance of these bodies in providing information is gratefully acknowledged.

Service (1967 - present), Chemical Abstracts Service (1970 - present), National Technical Information Service (ca. 1964 - present) and National Agricultural Library CAIN System (1970 - present).

The following bibliographies were consulted: Bibliography of Agriculture, Bibliography on Legal and Regulatory Aspects of Water Pollution, Control and Abatement (U.S. Dept. of Commerce, NTIS), IBM/360 Document Processing System, Water-Recreation Bibliography, and numerous smaller bibliographies relative to individual subject areas, such as snowmobiling, leadshot poisoning, recreational site management, marinas, etc.

Important primary information sources in the form of books and monographs, papers and reports in scientific and technical journals, symposia proceedings, official reports and documents, etc. which were identified as a result of these searches were examined and copied using the extensive library system of the University of Wisconsin, Madison. Some documents were purchased from the National Technical Information Service. Some reprints and manuscripts were obtained from authors. Articles of interest in popular recreational magazines were examined in the City of Madison Public Library or obtained as reprints from the magazine publishers.

A listing of the journals, books and documents consulted is too extensive to present here. The major sources of information have been cited in the reference section at the end of this report.

2.3.4 Assumptions Made

The overall impact of recreation and recreational land and water use on the quality of the waters in the Great Lakes and the Great Lakes Basin is assumed to be an extremely complex function of the total recreational land and water area, the nature of the land (e.g. BOR land classes), the nature of the waters (rivers, lakes, streams) and their hydrological characteristics, the intensity of use and the time and type of the recreational use in question (seasonal use, and nature of recreational activities).

It also is assumed that summation of these factors could give a simple first approximation as to the importance of recreation as a "diffuse source" of water pollution. Such an assessment is the intent of this report. However, values for many of the terms in this summation are lacking. It must therefore be assumed that these terms are negligible. Whether these are valid assumptions is open to question, when the reasons for the lack of some data and the weaknesses of other data are considered.

The question of the environmental impact of recreation has only recently become of concern, consequently it is commoner to encounter postulates or opinions in the literature on the subject rather than objective conclusions based on scientific method and data gathering. This applies equally to the overall impact and to the effect of individual activities. Suitable methodology for assessing environmental damage of recreation is frequently lacking from some of the specific questions examined. Even when statistics have been collected for a certain land use or recreational activity and pollutant loads have been measured, significant correlations cannot always be drawn; the number of affecting parameters and the variability in data is often simply too large. Moreover, conflicting results have sometimes been obtained in similar studies, reflecting the inadequacy of investigational methods. For what appears to be mainly emotional reasons, some aspects of recreation have received much more attention than others. The more "notorious" activities, such as snowmobiling, powerboating and motorcycling, which have jolted the public's awareness through noise and high incidence of severe accidents, have tended to come under closer scrutiny regarding their environmental impact than the more placid pastimes of canoeing and hiking. Consequently, quantitative measures for many recreational activities and their associated effects on land and water have never been accumulated.

Efforts to quantify the impact of recreation in the Great Lakes

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Basin are complicated by some other factors requiring additional minor assumptions. For many activities, the only quantitative data available has been derived from studies conducted outside the Basin. Direct transferral of findings from such studies to recreation in the Basin is not justifiable because of differences in climate, physical land features, etc. Appropriate weightings must be assumed for such differences.

To derive approximate total inputs for some activities, the product of the number of participants and the average contribution of one individual must be used. Statistics for the number of participants in the Basin are not always known, although frequently national estimates are. It is therefore assumed that, to a first approximation, the percentage of national activity in the Basin equals the percentage of the national population residing in the Basin. The resultant figure can then be modified to reflect the participation in the Basin, versus the remainder of the country, owing to factors such as climate or terrain resources.

Figures used for participation rates in the Basin are frequently derived from the Great Lakes Basin Framework Study Appendix on Recreation (124). These numbers are subject to the assumptions made in their derivation. Some of these can affect estimates quite seriously. For instance, it was assumed (124) that traffic flow patterns of recreationers emanating from Standard Metropolitan Statistical Areas are uniformly distributed. This causes an equalization in area use that does not occur in reality.

Traffic flow patterns are strongly vectorial and result in uneven loadings of recreational sites. Overloadings at certain localities can result in severe site deterioration and local water quality impairment although the effect appears negligible when averaged over the whole Basin.

Thus, it is important in considering effects of recreation to examine details of local situations, rather than averaged impacts.

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Section 3

REVIEW OF FINDINGS OF PREVIOUS STUDIES

3.1 General Description of Land Use Category

Recreational lands in the Great Lakes Basin and water resources associated with these lands exhibit a rich diversity of distribution, topography, vegetation, degree of development, use and ownership. Those aspects of the geological history of the Basin and its climatological features which influence recreation are summarized in the recreation appendix of the Great Lakes Basin Commission (GLBC) framework study (124).

The recreational land available in the Basin has been classified into six land use catagories according to the system employed by the USDI Bureau of Outdoor Recreation (61,124). Summary figures for the Basin are given in the first column of Table 1. Some important recreational attractions of the various sub-basins are given in Table 4. Totals of the amount of each land class for the various sub-basins are given in Table 5. It is apparent from these summaries, even without further breakdown, and from the present and projected figures for the populations of the various sub-basins in the system (cf. Fig. 3) that an inverse relationship exists between the availability and accessibility of recreational land, and the occurrence of large urban population centers in the Basin. This distribution results in over-use of public recreational lands located near metropolitan areas. Despite the high degree of development and high carrying capacity of these lands, large overloading occurs especially in connection with short-term visits (daily, weekend or national holiday use). Conversely, the larger recreational areas located some distance from highly populated areas are normally restricted to low density,

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TABLE 4

Recreation attractions of individual lake basins in the Great Lakes System

Basin	Lake Superior	Lake Michigan	Lake Huron	Lake Erie	Lake Ontario
National Parks	Isle Royal Voyageurs				Adirondack
National Lakeshores or Islands	Pictured Rocks Apostle Islands	Indian Dunes Sleeping Bear Dunes Green Bay Islands Beaver Islands	Patagannissing Bay Islands	Bass Island	Thousand Islands
National Forests A Ha		2,000,000 809,717	400,000 162,000		Portion of Green Mts. Nat'l Forest
State Forests A Ha	1,500,000 607,000	1,600,000 648,000	1,250,000 506,000		
Local Gov't Forests A Ha	650,000 263,000	500,000 202,000			
Wild, Scenic or Nat'l Rivers	Black Ontonagon Presque Isle Tahquamenon	Pere Marquette, Little Manistee, Manistee, Pine, Escanaba, Whitefish, Manistique, Muskegon, Pike Pine, Wolf, Brule, Fox Popple, Elkhart	Au Sable Carp Ocqueoc Rifle Black	Huron Clinton Sandusky Chagrin Maumee	
Special Features	Boundary Waters Canoe Area Huron Mts. Porcupine Mts.	Hundreds of inland lakes, with thousands of acres of beaches, 811,000 A of water area (328,340 Ha)	Many inland lakes, beaches, rivers; 140 A (57 Ha) public beach on L. Huron, Saginaw Bay Marshes		33 A (13 Ha) of public beach on L. Huron
Drawbacks/deficiencies	Lake temp. 35-65°F (1.6-18.3°C), too cold for swimming or waterskiing	Strong undertow at some beaches	Stong undertow at some beaches, 13 A (5.3 Ha) of beach polluted, many inland lakes highly developed, inadequate public access	Excessive residental & industrial development precludes recreational use of many suitable areas. L. St. Clair contaminated with mercury, 40 A (16 Ha) public beach in urban area polluted	

TABLE 5

Approximate distribution of recreation lands according to the BOR System in separate Great Lakes Drainage Basins
(Data from 124)

		L. Superior	L. Michigan	L. Huron	L. Erie	L. Ontario	Total
Class I	A	1,290	26,862	1,627	14,733	3,967	48,479
	Ha	522	10,875	659	5,965	1,606	19,627
Class II	A	14,313	86,356	15,889	37,662	75,728	229,948
	Ha	5,795	34,962	6,433	15,248	30,659	93,097
Class III	A	8,440,620	3,290,144	1,684,355	56,844	15,155	13,487,118
	Ha	3,417,255	1,332,042	681,925	23,014	6,136	5,460,372
Class IV	A	21,592	22,919	80	576	1,656	46,823
	Ha	8,742	9,279	32.4	233	670	18,956
Class V	A	1,226,407	3,397	0	700	3,155	1,233,659
	Ha	496,521	1,375	0	283.4	1,277	499,456
Class VI	A	2,115	837	35	342	1,348	4,677
	Ha	856	339	14.2	138.5	546	1,894
TOTAL	A	9,706,337	3,430,515	1,701,986	110,857	101,009	15,050,704
	Ha	3,929,691	1,388,872	689,064	44,882	40,894	6,093,402

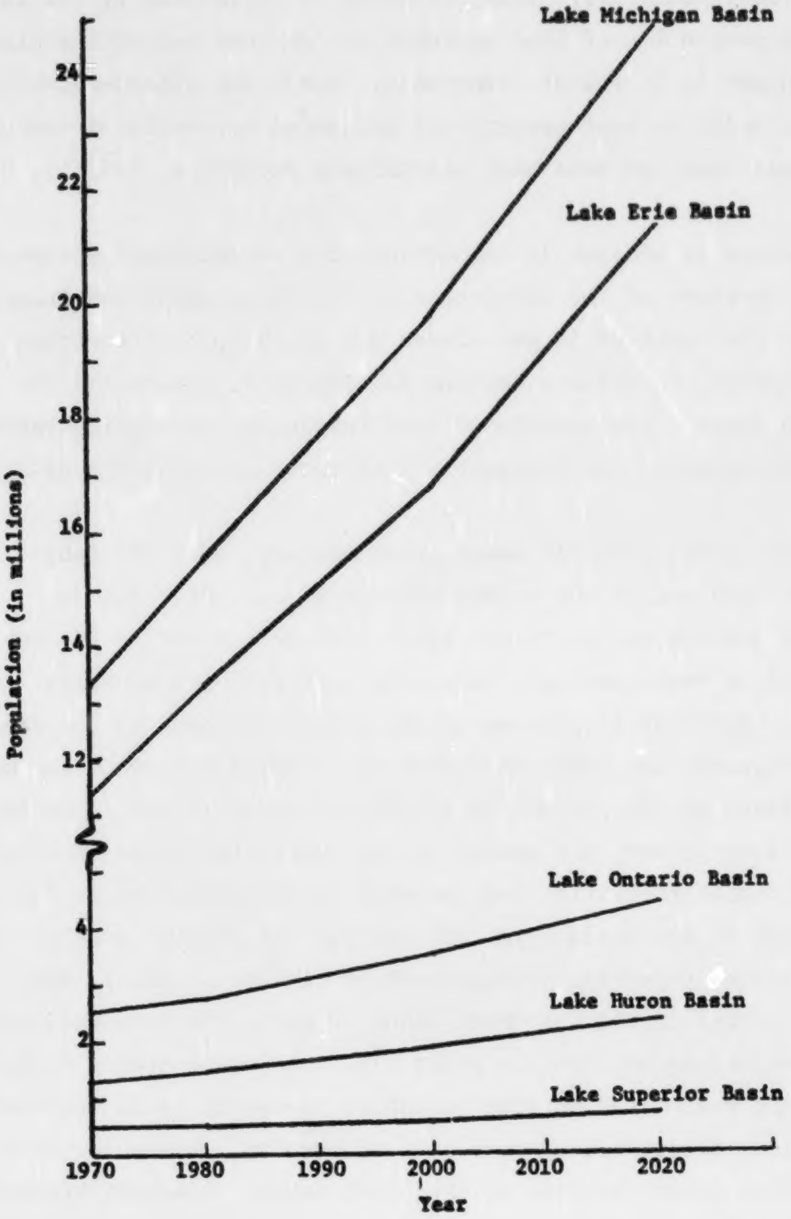

Figure 3. Population by lake basin in the Great Lakes System (Data from 122,124)

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long-term (vacational) use. This situation is aggravated by the fact that a major proportion of land suitable for outdoor activities close to urban centers is in private ownership. Needs for expanded public recreational lands to meet present and projected recreational demands are well recognized and have been extensively documented (35, 59, 61, 62, 124).

The picture is similar in connection with recreational waters in the Basin. Portions of the lakefronts on the Great Lakes and inland lakes and on the banks of larger rivers are taken up by industrial, highway, railroad, or private housing developments, especially in metropolitan areas. The amounts of land remaining for public beaches, parks or boat launches are frequently inadequate in densely populated regions.

The great Lakes have 110 small craft harbors, over 300 public access points and over 2,200 private access sites. Of 2,245 Ha (5,543 A) of beaches on the lakes, 41.4% (931 Ha = 2,298 A) are publicly owned and 90% of these are open to public use; 5.1% are unusable. Of the 1,314 Ha (3,245 A) of private beaches, 3.7% are open to the public; 76% of these charge admission for beach use. Privately owned beaches also predominate on the 850,500 Ha (2,100,000 A) of inland lakes in the Basin, although many are opened to the public for fees. Partial listings of public facilities are included in recreation plans for the various states in the Basin (e.g. 35) and for the various sub-basins within the system (62-66). A comprehensive listing of public and private facilities in all the Great Lakes is available in a national guide to campgrounds and trailer parks (24). In urban areas, "public" facilities are restricted in some townships to use by local residents as a mechanism of controlling recreational density. There is already a need for more public beaches on the Great Lakes. However, beaches on the Great Lakes are of dubious value because the water is too cold for prolonged swimming or waterskiing, making it more important to provide adequate public facilities in warmer inland lakes and rivers.*

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* State laws provide for public access to principal inland lakes.

A variety of recreational facilities and recreational activities can be associated with the various BOR classes of recreational lands. Class I lands, high density recreation areas, are assumed to be at least 50% developed. These lands include such areas as sports stadiums, playgrounds, ball-parks, racetracks, marinas, swimming pools, ski lodges, some campgrounds and swimming beaches, skating rinks, municipal parks, zoos, etc. Class I lands receive at least 4,942 visits/Ha/year (2,000/ visits/A/year. Historical, scenic and cultural sites (Class VI lands) are similar in loading, but constitute only a minor fraction of the recreational land in the Basin. Class II lands--general outdoor recreation areas--are lands subject to substantial development for a wide variety of specific recreational uses including areas that are 10 to 15% developed for intensive use, such as riding stables, some state and public parks, some campgrounds and swimming beaches. Such lands receive about 185 visitors/Ha/year (75 visitors/A/year). Most lands in the outstanding natural area category (Class IV) also receive about the same amount of use. Class III lands (natural environment areas) and Class V lands (primitive areas) encompass various types of land but mainly forest and wilderness suitable for such recreational activites as camping, canoeing and hunting, in virtually undeveloped environments. These areas though very extensive, receive only light use, i.e., about 5 to 7 visits/Ha/year (2 to 3 visits/A/year).

Average use figures are somewhat deceptive. Much higher use occurs in some parts of the Basin. In fact there is a latent unsatisfied demand for some activities: if more facilities were available, participation would increase spontaneously.

3.2 Length of Time Activities Have Been in Practice

As much diversity exists in the history of recreational activities as in the nature of the activities. Activities such as hunting, riding, fishing and canoeing were initially essential to the development of the Basin in the early 1800's and it is impossible to set a date when these undertakings became a recreational rather than a vital component of life in the Basin. Activities such as swimming, skating, sailing, sledding and nature walks were undoubtedly leisure devices of even the early settlers. Other activities, such as powerboating and driving expanded in the 1920's and 30's concomitant mass production of the internal combustion engine and automobiles.

Camping became popular in the 1930's as sites remote from industrial and urban areas became more accessible by road. Such organizations as the Boy Scouts of America and the 4-H Club did much to promote and perpetuate popularity of this activity. However, many now widely enjoyed recreational activities developed as a result of the upsurge in travel, technology and manufacturing methods that occurred during the second world war. Radio and television have popularized recreational participation by creating a greater awareness of recreational possibilities and opportunities for participation.

The tradition of recreational activity has however little significance for the importance of this facet of life as a potential factor affecting water quality. More importantly, good management has been employed to provide maximum satisfaction from recreational opportunity. In view of recognition of some effects that certain recreational pursuits may have on water quality, management practice can be adapted to control and eliminate deterioration in water quality resulting from use or abuse of recreational lands and waters.

3.3 Types and Nature of Pollutants Associated with Recreational Land and Water Uses

Deterioration of water quality as a result of recreational activities and recreational land and water use can result from direct, indirect or accelerated inputs of a variety of pollutants, including plant nutrients (especially nitrogen and phosphorus), organic wastes and detritus (BOD and COD loads), sediments, toxic elements and engine fumes, gasoline, oil and hydrocarbons, litter and solid wastes, pesticides and bacteria and virus. Some of the inputs are contributed from several types of land or activity, a few are highly specific to certain sports or land types. For example, erosion is a general natural phenomenon; the bulk of recreational lands (forest and wilderness areas) have extremely low erosion rates, but these increase rapidly with development and use. Losses of 0.36 metric T/Ha/yr (0.16 T/A/yr) of soil measured for two woodland-wildlife recreational areas were only 16% of losses from roads and building areas in one locality and 1.6% of losses from roadsides and ditches in the other (235). Similarly, accelerated erosion has been identified or associated in a general way with such sports as skiing, snowmobiling, riding, off-road vehicle use, and even with such apparently innocuous pastimes as hiking. Accelerated streambank erosion along hiking trails is frequently observed, according to the U.S. Soil Conservation Service (U.S. SCS) (121). Quantification of effects is difficult, because of lack of knowledge of the constancy and magnitudes of control values, the divergence in rates and extents of erosion, climatological influences, etc. However, studies have revealed many instances of massive effects with unstable soils under specific circumstances. Particularly endangered are the so-called red clay soils of Lake Superior (214). Developments on red clay soils of some recreational facilities e.g. parking lots or boating ramps, which would normally have no detrimental effects, have caused extensive sheet and gulley erosion.

Campsites in some Natural Forest areas also undergo severe erosion because of lack of suitable methodology for control in remote wilderness areas (210). Development of visitor conveniences (parking lots, toilet and concession buildings) at some scenic outlooks or historic sites can also alter drainage patterns so severely that massive erosion and site deterioration result, e.g., by bluff or shorebank erosion. Significant shorebank erosion also may result from powerboating on small lakes with unstable beaches and shorelines (217).

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Increased inputs of plant nutrient can originate from recreational lands and recreational activities. Some of these are minor, some are quite substantial. In some instances it is difficult to differentiate between inputs that are "natural" and inputs that are recreation-related e.g., wildfowl droppings. To place these inputs in perspective, it is worthwhile to consider the magnitude of N and P contributions from a variety of sources (Tables 3 and 6).

Natural "background" inputs of N and P are of the same order of magnitude as inputs from the bulk of recreational lands (forest and wilderness). Substantial amounts of N fixed by electrical storms and P from dust and particles in the air are deposited in lakes by rainfall. In addition, microbial fixation of N in sediments and lake waters by bacteria and blue-green algae makes further substantial contributions of N; 4.5-5.6 kg/Ha (4-5 lb/A) of N_2 can be fixed annually in areas of abundant algal bloom (54,158). Measurements have been made of this input to Lake Erie (107).

Although inputs of N and P from some recreational sources, e.g. unsewered homes, motels, campgrounds, ski lodges, etc., boat sewage, or riding trails and stables, may be very intense, overall they constitute only a small fraction of the total pollutional load from all sources (cf. Tables 3 and 6). However, these inputs should not be ignored since they can be mollified or eliminated by improved technology or management.

Sewage and swimming also contribute bacteria and possibly viruses to waters. Sewage and runoff from recreational lands, especially golfcourse thatch and detritus from parks on floodplains, occasionally add substantial BOD and COD loads. Toxic element inputs result from use of mercurial and arsenical fungicides on golfcourses, lead shot for wildfowl hunting, leaded gasoline for boat, snowmobile and land, off-road vehicle engines and copper for swimmer's itch control. Although organic pesticides are not used extensively on recreational land, some evidence suggests that loss of the materials occurs more readily from recreational than from other lands (187).

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TABLE 6

Sources and amounts of nitrogen and phosphorus entering lakes (data compiled and recalculated from a variety of sources)

Source	N		P	
	lb/A/ year	kg/Ha/ year	lb/A/ year	kg/Ha/ year
Forest runoff	1.5-5.6	1.7-6.3	0.095-0.97	0.106-1.09
Forest percolation water	0.6	0.67	0.038	0.043
Precipitation on lake	2-11	2.2-12.3	0.017-0.67	0.019-0.75
Pastureland	1.1-9.5	1.2-10.6	0.17-0.84	0.19-0.94
Cropland	5.6-135	6.3-151.2	0.25-1.1	0.28-1.23
	lb/person/ year	kg/person/ year	lb/person/ year	kg/person/ year
Septic tank effluent				
average	4.0	1.8	0.04	0.018
littoral	5.3-10.6	2.4-4.8	0.3-0.57	0.14-0.26
remote	2.2-5.7	1.0-2.6	0.03-0.057	0.014-0.026
Domestic Sewage (raw)	18	8.2	1.76	0.8
	lb/bird/ year	kg/bird/ year	lb/bird/ year	kg/bird/ year
Waterfowl	1.1-2.1	0.48-0.95	0.1-0.2	0.05-0.09

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Some recreation-related inputs are so specialized, and findings concerning their impact so controversial that the peculiar situations relative to important individual recreational activities are discussed more fully in Section No. 3.4. Estimates made on the basis of the few measurements available for the total production or inputs of pollutants from several recreational activities are summarized in Table 7.

3.4 State-of-the-Art in Assessing and Quantifying Problems

3.4.1 Introduction

Standard methods of water sampling and water analysis have been used extensively to determine water quality in relation to recreational pursuits and to assess nutrient and pollutant loadings from specific recreational activities or land and water uses. Parameters frequently examined include solid wastes, suspended solids, volatile suspended solids, BOD_5, COD, total Kjeldahl N, NO_3^--, NH_4^+- and organic-N, total-, soluble-, inorganic-, and organic-P, total bacteria and total fecal coliforms, and trace elements. In addition, auxiliary methods have been used for specific studies, e.g. gas chromatography for hydrocarbon or pesticide assays.

Information concerning various types of recreation hazards to water quality are discussed in the following subsections. The activities are presented mainly in order of popularity, as measured in annual recreational days but this sequence does not imply any priority or rating in the seriousness of the environmental impact.

3.4.2 Swimming

Swimming is the fourth greatest recreation activity in the Basin, after outdoor games, pleasure driving and walking (124). This sport is the most popular water-oriented activity. In terms of annual recreation days, the 1970 level of participation in swimming (64.8

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TABLE 7

Estimates of total annual production of pollutants and pollutant inputs into waters in the Great Lakes Basin from a variety of recreational activities.

Activity	Sediment	Solid Waste	Measured Parameters
Driving for pleasure	2.24-22.4 metric T/ha/yr	0.018-0.084 Kg/person/day 1787-4383 metric T/yr	
Walking for pleasure	2.24-8.96 metric T/ha/yr		
Playing outdoor games or sports	2.24-8.96 metric T/ha/yr	0.0091 Kg/person/day 1274 metric T/yr	BOD₅ 13 Kg/ha/yr; COD 67 Kg/ha/yr; Organic N 1.3 Kg/ha/yr; Ortho-P 1.3 Kg/ha/yr; Total solids 720 Kg/ha/yr
Sightseeing	2.24-11.2 metric T/ha/yr	0.0091 Kg/person/day 408 metric T/yr	
Bathing, Swimming		0.018 Kg/swimmer/day 1899 metric T/yr	$CuSO_4$ up to 88 Kg/ha/yr
Bicycling	2.24-8.96 metric T/ha/yr		
Picnicking		0.422-0.828 Kg/picnicker/day 18,274-28,409 metric T/yr	
Attending outdoor sports events	2.24-8.96 metric T/ha/yr	0.018-0.084 Kg/person/day 122-1656 metric T/yr	
Fishing	2.24-11.2 metric T/ha/yr	0.018 Kg/person/day 322 metric T/yr	BOD_5 Fish hatchery waste 1.23-2.45 Kg; COD fish hatchery waste 3.00-5.38 Kg; (Power boats 78% of total) HC 34,200 metric T/yr; CO 71,000 metric T/yr; NO_x 140 metric T/yr; SO_x 78 metric T/yr
Nature walks	2.24-11.2 metric T/ha/yr	0.018 Kg/person/day 189 metric T/yr	
Power boating (cruising)	2.24-11.2 metric T/ha/yr	0.018-0.084 Kg/person/day, 394-1,402 metric T/yr	(Cruising 35% of total) HC 19,000 metric T/yr, CO 32,000 metric T/yr, NO_x 69 metric T/yr, SO_x 35 metric T/yr
Hunting	2.24-8.96 metric T/ha/yr	0.7 Kg/person/day 5,850 metric T/ha/yr	Pellets from lead shot, 14,800-296,400/ha. Game farm wastes, 80-[illegible] g/waterfowl/day; N-5.9 Kg/ha, P-7.77 Kg/ha
Ice skating			
Horseback riding	2.24-11.2 metric T/ha/yr	0.018 Kg/person/day 148 metric T/yr	Solid & liquid horse waste; 20 Kg/day/horse; 6.6-7.3 metric T/yr/horse; 10,900,000 metric T/yr
Camping, summer homes	2.24-11.2 metric T/ha/yr	0.58 Kg/day/person 4,082 metric T/yr	
Sledding & tobogganing	2.24-8.96 metric T/ha/yr		
Attending outdoor artistic events	2.24-8.96 metric T/ha/yr	0.018-0.084 Kg/person/day, 72-238 metric T/yr	
Hiking	2.24-8.96 metric T/ha/yr	0.018 Kg/person/day 70 metric T/yr	
Water skiing	2.24-11.2 metric T/ha/yr	0.018-0.084 Kg/person/day 70-210 metric T/yr	(Power boats 27% of total) HC 8,400 metric T/yr; CO 24,800 metric T/yr; NO_x 49 metric T/yr; SO_x 27 metric T/yr
Canoeing	2.24-8.96 metric T/ha/yr	0.018-0.084 Kg/person/day 25-90 metric T/yr	
Sailing		0.0091 Kg/person/day 12 metric T/yr	
Snow skiing	2.24-8.96 metric T/ha/yr	0.05-1.35 Kg/person/day 1918-2036 metric T/yr	
Snowmobiles	2.24-8.96 metric T/ha/yr	0.018-0.084 Kg/person/day 504-1792 metric T/yr	Lead 30-60 μg/l; HCHO 443 metric T/yr; HC 30,430 metric T/yr CO 47,300 metric T/yr; NO_x 484 metric T/yr; SO_x 41 metric T/yr; particulate matter 2970 metric T/yr
Off-road recreation vehicles	Up to 52.0 m^3/ha/yr	0.018-0.084 Kg/person/day 36-128 metric T/yr	HC 18,876 metric T/yr; CO 60,448 metric T/yr; NO_x 294 metric T/yr; SO_x 38 metric T/yr
Rock climbing	2.24-8.96 metric T/ha/yr		

NOTE: 1 metric T/ha = .446 T/A; 1 metric T = 1.1 T; 1 Kg/ha = .892 lbs/A; 1 Kg = 2.2 lbs; 1 m^3/ha = .51 yd^3/A

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million) is expected to more than triple by 2020 (213.9 million) cf. Table 20).

Swimming has been identified as the most popular outdoor activity in Wisconsin, accounting for 27.3% of the total recreation occasions (39). In Wisconsin (35) children under 12 years of age accounted for 30% of total swimming participation. The input by this age group is substantial but frequently neglected in many counts or estimates of swimming activity. Approximately 70% of all resident swimming activity takes place on a day-use basis rather than in association with trips. In Wisconsin 98% of the swimming beaches had backup lands used by swimmers; these were multiple purpose areas and/or campgrounds.

Over 2,248 Ha (5,550 A) of Great Lakes beaches exist. Public beaches usable and open to the public represent about 37% of the total, while privately owned beaches open to the public account for only 4% of the total. The remaining 59% (1,316 Ha = 3,250 A) are closed to the public. This problem of accessibility is similar with the areas of unknown total size of inland lake beaches. Consequently, there is an uneven density distribution in the use of areas suitable for swimming.

Because of public health considerations, the quality of water used for swimming has long been a matter of concern. However, differences exist in water quality standards used for evaluating conditions in waters designated for recreational use. For years, the following general criteria were applied (118):

(a) For whole body contact, total coliform counts must not exceed 1,000/100 ml of water as a monthly-average value during any month of the recreational season (April 1-Oct. 31) nor exceed this number in more than 20% of the samples examined during any month of the season.

(b) For partial body contact, coliform counts must not exceed 5,000/100 ml of water as a monthly-average value, nor exceed this number in more than 20% of the samples examined during any month, nor exceed 20,000/100 ml in more than 5% of such samples.

The U.S. EPA (8) now recommends that the fecal coliform group of bacteria should be used as indicator organisms for potential contamination of surface waters by human pathogens. The acceptable standards for fecal coliforms were set at 2,000 per 100 ml of water as an average with a maximum of 4,000 per 100 ml for partial body contact and at a log mean of 200 per 100 ml for whole body contact, provided no more than 10% of total samples during any 30-day period exceed 400/100ml. Testing of at least 5 samples per 30-day portion of the recreation season by multiple-tube fermentation or membrane filtration was prescribed. The EPA has also set standards for clarity, temperature and pH (6.5-8.3) of waters. No limits for viruses in recreational waters have been prescribed.

Effects of natural variations in bacterial ecosystems have not been taken into account when the bacterial standards for recreational waters have been set. Standards set solely on counts of coliforms or coliform subgroups may have ignored important health problems unrelated to fecal contamination of bathing waters (92,105,212).

The value of the coliform test as a health hazard indicator has recently been challenged (58,92,113,149), principally because no proof exists of any direct association of disease or epidemics with high coliform counts. Some of the shortcomings of the coliform index relate to bacteriological characteristics of the organisms. For instance, coliforms multiply in nutrient-rich waters, but so far no evidence has been found that pathogens do. Consequently, coliforms which survive chlorination in sewage treatment may multiply to prechlorination levels, producing specious indications of a potential health hazard. Coliforms are difficult to differentiate from other enterobacteria using certain media; the true count may be only 5-60% of the total bacteria measured (149).

The coliform standard may therefore be overcautious and result in deprivation of swimming opportunities in some condemned waters which are actually safe. Since illnesses contracted through swimming are normally ear, nose and throat ailments or skin diseases, standards based on pathogens which cause these maladies, such as pseudomonads, staphylococci, streptococci and fungi, would be preferable (57,58,111,113,142,149). Nevertheless, in a recent thorough review and reassessment of the value of the fecal coliform test, it was still considered to be the most reliable and realistic method for determining potential health hazards due to recent inputs of feces of warm-blooded animals into water (112).

Fecal coliform counts are unquestionably still good indicators of contamination of water by sewage--a factor which influences its desireability for swimming activities. In view of the clause in the EPA regulations, excluding only 10% of samples taken within a 30-day period, the common practice of weekly sampling at swimming beaches is inadequate. Sampling frequencies should be increased in popular swimming areas during high use periods (260). Some attention has recently been devoted to antibiotic-resistant coliforms, which may transfer this resistance in bathing waters to typhoid salmonella (215,230).

Some contamination of water may arise from swimmers themselves, and *en masse* they too can have sizeable effects on water quality. From the point of view of the water, swimming is literally a "body contact" sport, and bacterial contamination from swimmer's bodies can result. Beach erosion, littering and stirring up of bottom sediments are secondary problems associated with swimmers. Accelerated siltation can arise from annual additions of clean sand to "family" swimming beaches, which are used extensively by children, and from dumping of sand or gravel in some waters to control nuisance plant growth.

A few studies have been conducted on the effects of bathers on water quality. One indicated that potentially large numbers of bacteria were contributed to bathing water; however, only five subjects participated in this study and all were females (218).

A later model study (129) using 64 male and female adults and children in a 10,595 liter (2,800 gal) swimming pool confirmed that swimmers have a considerable influence on the chemical and bacterial quality of water. Bathing resulted in a large but highly variable number of bacteria, but only a small percentage of the total bacteria (0.174% coliforms, 0.025% enterococci) were of fecal origin. According to median values,

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the average bather contributed 3 fecal coliforms, 4-5 enterococci and 484 total coliforms/100 ml of water during a 15 to 30 minute swim. Inputs were therefore substantial, but not high enough to disqualify the water for safe swimming. Mean counts indicate inputs of 10 fecal coliforms, 30 enterococci and 2,174 total coliforms per 100 ml of water per average swimmer. Body secretions resulted in increases in water turbidity and NH_4-N content, regardless of the amount of time bathers spent in the water. Studies of swimming areas in rivers revealed a direct relationship between the number of swimmers and the turbidity of the water, caused by agitation of the bottom sediments. At times the fecal coliform count rose to above 600/100 ml (154). This demonstrates that coliform counts above the EPA standards can result from swimmer body contact in natural outdoor swimming areas as well as in experimental pools (154).

Means of detection of organisms in swimming waters and methods of control have been discussed in a critical review (185). Most methods of control involve additions of chemicals to the water and may therefore be considered as recreation-related pollution inputs. A case in point involves the effect of control of swimmer's itch on water quality. Copper sulfate mixed with lime is added to some lakes and beaches annually at a rate of 90 kg/Ha (80 lb/A) to control the snails which act as host to the flatworm causing the disease, and the cercaria stage of the worm's life cycle which attacks swimmers (172).

Approximately 455 metric T (500T) of Cu have been added in this way since 1944 to Lake Houghton in Michigan (200). However, Cu in the lake water is still below detectable limits (<10 ppb), unless associated with particulate matter (20-750 ppb). Sediment contains 1.4-255 ppm of Cu; organic sediments in deeper parts of the lake are particularly enriched. Gamefish contained 0.4-1.7 ppm Cu; controls from other waters contained only 0.2-0.7 ppm Cu. Benthic macrovertebrates contained highly enriched levels (3-48 ppm). The cation exchange capacity of the organic sediments in Lake Houghton can provide for an uptake of 8,700 ppm of Cu before toxic levels would arise in the waters.

In other treated lakes, the highest concentrations of Cu occurred in the upper foot of lake bottom sediment (78,228). Since Cu is bound to the sediments it is not easily leached (222). Resuspension of sediments by bathing activities in treated areas is therefore unlikely to cause problems. Nevertheless, other methods of swimmer's itch control, e.g., biological methods, should be sought to eliminate costly Cu treatments, which might prove hazardous used on a continual basis.

Overall, swimming appears to have only insignificant impact on water quality, perhaps with the exception of extensive use of domestic water reservoirs for swimming. Because drinking water is constantly disinfected and monitored before use, even this does not appear to be a problem. More important is the effect that other sources of pollution have on waters used for swimming.

3.4.3 Boating

Boating is one of the principal recreational activities in the Great Lakes Basin. Powerboats are used for pleasure riding, water-skiing and fishing. Surveys in Wisconsin in 1970 showed that boating accounts for 9.1% of total recreation occasions and water-skiing for 3.7% (39). Projections for 1980 and 1990 suggest that these rates of participation will continue at similar levels.

Prior to 1900, water ways were routes of commerce, and little thought was given to the recreational boating potential of U.S. rivers and lakes. With the development of the internal combustion engine, engine and boat manufacturers collaborated to design and construct units for recreational use. Since the early 1900's the number of boats used for recreation has increased from an estimated 15,000 in 1904 (120) to 9.5 million (5) in 1973 (cf. Fig. 4).

The growth in popularity of boating can be credited in part to technical and economic factors: advancement in boat and motor design, development of more powerful engines for high speed water travel and water-skiing, development of self-launching boat trailers and increased

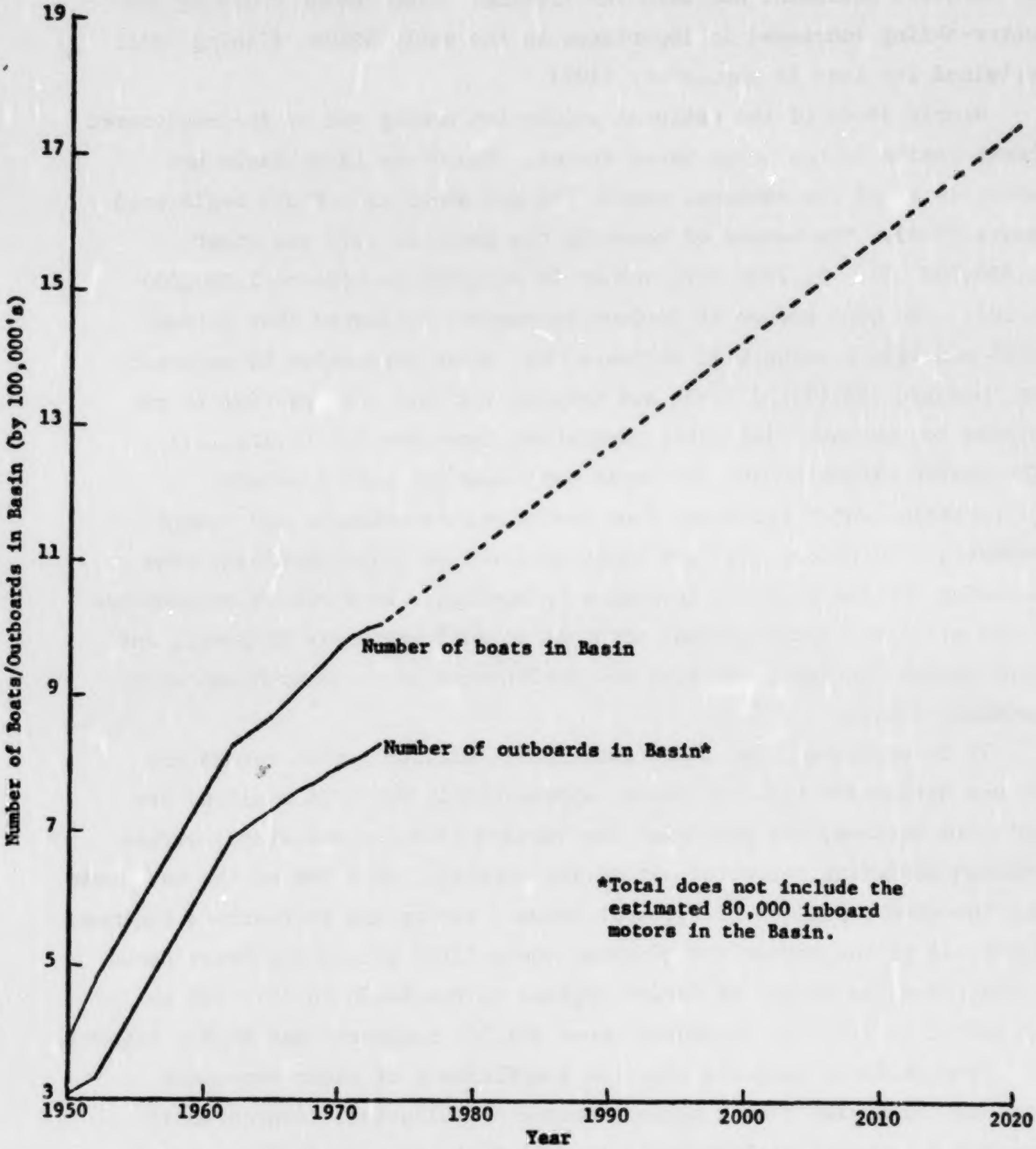

Figure 4. Number of boats and outboards in the Great Lakes Basin (based on data from 5,120,124).

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personal income and leisure time.

Since 1953, when data were first collected, the most popular use of outboard equipment has been for fishing. Even though cruising and water-skiing increased in importance in the early 1960s, fishing still retained its lead in popularity (120).

Nearly 36.8% of the national population owning 40% of the registered boats reside in the Great Lakes States. The Great Lakes Basin has about 14.8% of the national population and about 11% of all registered boats (120). The number of boats in the Basin in 1973 was about 1,038,000 (5). By 2020 this number is expected to rise to 1,754,000 (120). The USDI Bureau of Outdoor Recreation estimated that between 1965 and 1980 boating will increase 76%, while population is expected to increase 29% (9,122,124); and between 1965 and 2000 boating is predicted to increase 215% while population increases 76% (9,122,124). The number of powerboats and their expanding use pose problems of potential water pollution from marine engine exhausts and sewage. However, indications are that these need not be major problems, even allowing for the expected increases in boating. As a result of positive legislation and technological advances in sanitary waste disposal, and improvements in engine design, the seriousness of these problems will probably lessen.

It is estimated that approximately 8.4 million marine motors are in use nationwide (5). Of these, approximately 90% (7.5 million) are outboard engines, the remainder are inboard gasoline and diesel marine engines including converted automotive engines. Over 98% of the outboards are two-stroke engines (194); most inboard motors are four-stroke engines. About 11% of the nation's registered boats (120) are in the Great Lakes Basin, thus the number of marine engines in the Basin in 1973 can be estimated at 924,000, including about 826,000 outboards and 98,000 inboards.

Some evidence suggests that the inefficiency of older two-cycle engines could make them a serious source of pollution. Conventional two-cycle outboard engines lose unburned fuel mixture via the subsurface exhaust port. Unburned oil from fuel-oil mixtures used for internal lubrication in such engines has a tendency to build up in the crankcase. If this excess is not removed, it causes the engine to malfunction, and can cause engine damage. Consequently, older outboards have valves to permit the excess mix to drain into the exhaust passage and discharge into the water (152). Estimates made of fuel losses from two-cycle outboards range from 1 to 56% (1,23,103,194,203) with averages of 10 to 20% (194). Modern crankcase design in new engines allows recycling of this drainage into the combustion chamber (21,197,237). However, the majority of boats still in use are powered by older engines but recycling devices are available (36). Many of these need a 25:1 gasoline:oil mix, versus 50:1 for modern engines.

Of the 3.8 billion liters (1 billion gal) of gasoline consumed annually by outboard motors, it has been estimated that 380 to 600 million liters (100-160 million gal) of fuel are wasted into receiving waters (197). Calculations based on fuel taxes indicate that approximately 190 million liters (50 million gal) or 5% of the annual consumption are used to operate outboard engines in Wisconsin alone (33). Thus, 19 to 38 million liters (5-10 million gal) of unburned gasoline/oil mixture could be discharged annually into Wisconsin's surface waters (33).

Studies on engine size (horsepower) and fuel-oil mixture proportions have resulted in contrasting findings. Two studies (1,6) found the most inefficent fuel use in smaller outboard motors, while a third (36) found that higher horsepower outboards wasted more fuel. Numerous studies concluded that outboards run less efficiently at low engine speeds (1,103,194).

Two-stroke outboards discharge a variety of compounds into receiving waters. While the most notable is raw fuel, other compounds measured in waters receiving outboard motor exhaust include nonvolatile oil, volatile oil, lead and phenols; inputs of these materials in g/liter of fuel consumed were 2-28 (0.017-0.234 lb/gal), 2-15 (0.017-0.125 lb/gal, 0.03-0.14 (0.0003-0.001 lb/gal) and 0.16-0.20 (0.001-0.002 lb/gal) respectively (6,93,96,159,258).

The resultant COD measured varied from 60-110 g/liter (0.501-0.918 lb/gal) (159) to 119 g/liter (0.993 lb/gal) (96) of fuel used.

Calculations of the national impact from marine engine exhaust of hydrocarbons, CO, CO_2 NO_x SO_x for both air and water phases are shown in Tables 8 and 9 (131). These figures are only a minor part of the national or mobile source totals. However, outboard exhausts enter water directly, and their impact maybe disproportionately large. Several studies have been conducted to try to answer this specific question.

In an industry study involving a 567 Ha (1,400 A) Florida lake (6), excessive inputs of exhaust from engines with and without crankcase drainage, using equal amounts of leaded and unleaded fuels (1,288,649 liters = 340,552 gallons of 50:1 fuel:oil mixture per year for 4 years) did not a. cause contamination of the water or sediment by hydrocarbons, b. produce fish kill, or c. damage phytoplankton or benthic organisms. Similar results were found in nearby smaller Florida lakes. Lead levels were below 20 ppb. The loading corresponds to an average input of 190 boats/Ha (77 boats/A) for 8 hours a day for a 6-month season. This boat density is three times higher than peak use counted on a July 4th weekend on Lake Geneva, Wisconsin, a popular boating lake, and is therefore unrealistically exaggerated. However, the study lake is somewhat atypical; being rather shallow (ave. depth 3.66 meters = 12 feet), it is nonstratified and located in a warm climate. These factors promote microbial decomposition of hydrocarbons when compared with conditions in colder, deeper Northern lakes. On the other hand, the dilution factor is less, 1 volume of fuel having been consumed for every 16,000 volumes of lake water per year. This is below the 1:19,000 dilution recommended in a early study as a safe level for fish (97).* Dilution in deeper lakes would be much greater.

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* As a rule of thumb, 0.003 liter/meter^3 (1 gallon/acre-foot) of fuel: lake water is now considered to cause odor and taste problems in gamefish.

TABLE 8

Approximate composite emission factors for use in small-scale outboard motor impact estimates (Data from 131)

Emission Unit	Qualifications	Medium Affected	Exhaust Constituent				
			Hydro-Carbons	CO	CO_2	NOx	SOx
g/joule	1	Atmos	31.6	93.8	144.5	0.19	0.18
		Water $\times 10^{-6}$	18.8	4.8	98.7	0.03	0.01
		Total	50.4	98.6	243.2	0.22	0.19
g/liter fuel		Atmos.	132.88	393.63	607.61	0.793	0.766
		Water	78.99	20.32	414.76	0.143	0.042
		Total	211.87	413.95	1,022.37	0.936	0.808
g/motor hr	2	Atmos.	769.	2,280.	3,510.	4.5	4.4
		Water	457.	118.	2,400.	0.83	0.25
		Total	1,230.	2,400.	5,910	5.3	4.6
kg/motor yr	2,3	Atmos.	38.4	114.	176.	0.230	0.220
		Water	22.9	5.88	120.	0.042	0.012
		Total	61.3	120.	296.	0.270	0.230

List of qualifications:

1 Engine rated hp should be multiplied by applicable load factor before using this unit.

2 Based on 24.6 rated hp per motor and average load factor of 0.368

3 Based on 50 hr usage per year

Conversion factors:

g/joule = 8.227 X 10^{-10} lb/hp-hr
g/liter fuel = 8.3655 X 10^{-3} lb/gal fuel
g/motor hr = 0.00221 lb/motor hr
kg/motor yr = 2.21 lb/motor yr

TABLE 9

Comparison of outboard national impact estimates with EPA nationwide air pollutant inventory data (131)

Contaminant	EPA Inventory Data 1970 10^6 tons/yr		Outboard Atmospheric Estimates as % of	
	All Sources	Mobile Sources	All Sources	Mobile Sources
Hydrocarbons	34.7	19.5	0.893	1.59
CO	147.	111.	0.624	0.826
NOx	22.7	11.7	0.0079	0.015
SOx	33.9	1.0	0.0029	0.10

Conversion factor: 1 ton = 0.91 metric ton

In a parallel study, Michigan lakes were loaded intermittently, corresponding to seasonal boating patterns; analyses of water and sediment have not yet been published, but are claimed to parallel the results for the Florida lake (56).

An independent study of Houghton Lake, a large (8,118 Ha = 20,044 A), shallow (average depth = 2.59 meter = 8.5 feet) lake in Michigan, heavily used for boating, revealed a fuel to lake water dilution ratio of 1:225,000 (205), a level roughly 50% below values that result in fish tainting (97). No lead could be detected in the lake water (level <10 µg/g), and sediment samples collected close to marinas did not exhibit elevated lead contents resulting from fuel spills. Lead levels in fish were slightly elevated. The question whether the safe level of engine emissions resulting from summer boating in this lake could be detrimentally supplemented by snowmobile and car traffic on the frozen lake in winter could not be answered. Surface ice from high use areas contained 30-50 ppb lead and 2 ppm oil, but, neither traffic nor pollutant loads could be effectively quantified (97).

Overall, boating engine emissions *per se* do not appear to be toxic to fish and aquatic life at levels resulting from normal outboard engine use (205).

The effects of outboard motor operations on water quality and possible biological effects of outboard motor pollution have been reviewed briefly in several publications (6,151,205,223). One important question has however received only minor attention. Some of the hydrocarbons emitted in engine exhaust are polynuclear aromatics, which may cause cancer. One hour of outboard engine operation deposits 0.5 mg (1.76 x 10^{-5} oz) of the potent carcinogen benzopyrene in water (147). This compound is one of the constituents of cigarette smoke "tars" and produces carcinomas when applied in low concentrations to the skin of experimental animals.

With regard to the disposal of on-board waste water, the Boating Industry Association estimates that there are 317,000 boats equipped with toilets in the U.S. (14); this figure conflicts with the USDI estimate of 1.34 million (102). No estimates are available for the number of such boats in the Basin.

Fresh feces and other body wastes may contain pathogenic organisms and viruses; these represent a potential health hazard. Sewage wastes in general cause a serious degradation of waters used for swimming, fishing, shell fishing, water-skiing, boating and other activities. Some of the pathogens concerned can cause dysentery, shigellosis, typhoid or paratyphoid fevers, gastroenteritis and infectious hepatitis. Aside from public health concerns, the mere presence of fecal matter, toilet paper, etc., in recreational waters is always esthetically objectionable.

In 1972, the EPA issued federal standards requiring holding tanks on all vessels, to go into effect 2 years after the U.S. Coast Guard (USCG) issued rules and regulations for new boats, or 5 years for existing boats. Older boats may install USCG approved macerator-chlorinater heads within the 3-year span and use these until they wear out, but at the latest until 1980 (4). Proposed Coast Guard Standards were issued on March 1, 1974 (43).

The majority of states, including all the Great Lakes States have laws to regulate vessel discharges. These laws are generally directed towards sewage discharges from recreation watercraft and largely supercede the U.S.EPA requirements. However, the extent of enforcement of these laws in the Basin States is at present variable. Two examples of local regulations are of merit.

Chicago has an ordinance requiring watercraft using the Lake Michigan harbor area to be equipped with holding tanks for onshore sewage disposal. Wisconsin law prescribes that on-board sewage holding devices be sealed as an aid in enforcing proper onshore pumpout practice.

Several bacteriological investigations of pollution due to recreational watercraft have shown that watercraft wastes create problems for water contact activities and for shellfish water conditions (102,144,148,153). Furthermore, (225) boat wastes raised the mean fecal coliform count in a fresh water body by 11% during the boating season (473/100 ml) over the non-boating season level (427/100 ml). Both levels are above the EPA

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standards for swimming. Counts in areas unaffected by boating were much lower and decreased by 61% during the warmer boating season (23 versus 7/100 ml). Physical, chemical and environmental factors and the complex nature of enteric organisms account for the normal decrease in mean fecal coliform count during the warmer boating season. Analogous trends were found in sea water: areas near boat moorages exhibited a serious influence of small craft wastes on water quality by producing high bacterial counts. Coliform counts in other marina areas also showed an increase (88,181,260). However, one study (17) claims that marinas are not major polluters. The explanation of these contrasting views may be found in the fluctuations in the levels that occur depending upon seasonal boating patterns. Peaks of activity on holidays were associated with significantly higher total coliform and fecal coliform and streptococi counts. Total coliform levels in excess of EPA standards result from this intensified use, especially in marina areas (38).

A variety of watercraft waste pollution devices is discussed at length in several documents (56,114,115,225,244). The question of collection and disposal of houseboat wastes has also been examined (75,76).

A possible problem of an insufficient number of on-shore pumpout terminals is humorously exaggerated in the following poem:

The Plight of the Modern Mariner (243)

Twas summer, Nineteen Seventy.
Assisted by the bank,
Our ship complied with Michigan's rules
And got a holding tank.

Vacation time came in July
We scraped and caulked the hull.
And loaded up our duffle--but
The holding tank was full.

"Oh dock boy can you pump us out?
Our tank is full, we fear."
"You're welcome to our rest rooms
But we cannot pump you here.

We're waiting for our pumps to come;
But for your consolation,
Just ten miles south, the State has built
A brand new pumping station.

So start your cruise without a qualm.
They're there to help you out."
And off we went with minds at ease
A short delay, no doubt.

"Oh station tender, can you help?"
"Yes! Come in August--late.
I've got two thousand boats to serve;
You're nineteen forty-eight."

We took our chances and went on
With stops at every pier.
We came to dread that fearsom cry;
"you cannot pump out here!"

Vacation's end was drawing near.
Our hearts were growing faint.
Oh Water! Water! everywhere
And not a drop to taint.

Now falling leaves pollute the bay,
And hot drinks fill the cup;
But joy is in our ship again.
Our number just came up.

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As improved devices for all sizes of watercraft become available, and more onshore pumpout and treatment terminals are installed, more extensive compliance with existing sewage dumping regulations is expected to occur. Eradication of this pollution source is therefore anticipated within the next few years, and before 1980 at the latest. However, at present boat sewage constitutes perhaps the most serious biological pollution hazard affecting water quality in the Great Lakes Basin from any recreational source.

Erosion of shores of small lakes or reservoirs by waves created by powerboats is said to be a serious problem unless adequate protective measures are taken (217). A powerboat pulling a water-skier about 91 meters (100 yards) offshore produces waves that exert pressures of 2,440-4,880 kg/m^2(500-1,000 lb/ft^2) onshore. Resultant erosion can be controlled either by suitable barrier construction or by enforcement of strict rules for boat operation (e.g. horsepower limits).

3.4.4 Snowmobiling

Snowmobiling is a relatively new activity, whose impact on the environment is becoming more serious every year. A phenomenal growth in the number of vehicles in use has been observed since their commericial introduction in the 1960's. Predictions are that future development will parallel growth in the recreational use of boats.

In 1962, there were only about 4,000 motorized sleds in Canada and the U.S. (130) but in 1965, there were 70,000 and in 1968 the number had jumped to 110,000 (130). In 1970 over 500,000 snowmobiles were sold in North America (140). Snow Goer Magazine (11) estimates the number of registered and unregistered machines to be more than 2 million in the U.S. and Canada. Wisconsin alone had 153,000 registered snowmobiles in 1972, the first year of registration, 175,000 in Jan. 1973, 212,000 in Jan. 1974 and 235,000 in March of 1974. Michigan had 68,120 registered snowmobiles in June of 1969 (89) and 127,269 in March 1970 (166). In August 1973, the number had increased to 354,163. As of Aug. 1973, Minnesota had 328,000 registered vehicles, while New

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York had 144,000 snowmobiles registered in 1971 (276) and 201,000 in Aug. 1973. From these data it was estimated that about 1.5 million machines are located in the Great Lakes States; the number of machines in the Great Lakes Basin is placed at about 1.2 million.

The International Snowmobile Industry Association expects the Great Lakes area to be the highest potential sales area in the United States because of the climate and "high density, recreation-minded population" (130).

Because of the rapid expansion of the sport, many conflicts of recreational interest and abuses have arisen, e.g. conflicts with other trail activities, downhill skiing, hunting and fishing (195). Although no data are available to support the contention, ice fishermen claim that snowmobiles running on frozen lakes disturb the fish. Charges have also been made that snowmobiles affect septic tank systems by causing tiled fields to collapse, since ground frost goes deeper where tracts have compressed the snow cover (130).

The careless use of snowmobiles is reported to result in devastation to the landscape in some areas where snow conditions are less than adequate. Three to five feet* of snow are said to be needed to cushion and protect the land (130).

Snowmobiling is similar to powerboating as a recreational activity. Snowmobiling tends to be a family activity: over 80% of the respondents of snowmobile owning families interviewed in Michigan stated that the entire household participated in the sport (89). As such, weekday activity is mostly limited to adults except during Christmas and mid-term school vacations.

While racing, hunting and rallies are important sidelights to this activity, trail riding and sight-seeing are the primary vacation motivators. Trail riding attracts 46.7% of snowmobile users (89). Estimates on the amount of snowmobile trails in the Basin are placed at 16,094-17,703 km (10,000-11,000 miles) (124).

Research findings indicate that snowmobiles have measurable

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* Misprint in original suspected--should be inches.

effects on the environment, in some cases detrimental effects, but that properly operated vehicles cause no serious harm to plants or animals. The impact of snowmobiles on soils and vegetation is important because damage to bare soil or vegetative cover can accelerate erosion and cause sediment inputs into lake and streams.

In recent studies (104,206), typical forage crops and grasses in four areas of Wisconsin were subjected to different amounts of snowmobile traffic for two winters. Where snow cover exceeded three inches in depth no detrimental effects were observed on grass or vegetation stands, or on plant vigor and yields. High-grade grasses recover naturally from heavy snowmobile traffic. With light snow cover, some alfalfa stands were damaged in areas of extensive use, the damage depending upon snow depth and type. Discretion by operators can lessen injury.

Plant damage does not occur by soil compaction: soil bulk densities for tested areas and control areas were identical. Instead, overground factors such as cooler temperatures or smothering effects of compacted snow or ice sheets were held responsible. Soil surface temperatures under intensively used tracts (364 passes) were -15°C (5°F) lower than normal. Snowmobile traffic on bluegrass plots at two sites caused no yield reductions, but did cause a slower recovery in early spring.

An industrial snowmobile testing area showed no serious compaction under a good coverning of snow (168). Snowmobiles were claimed to exert less than 0.035 kg/cm^2 (0.5 psi) pressure on the ground vs. 0.193 kg/cm^2 (2.75 psi) for human feet. Compaction was said not to occur on a test area that received year round testing, but no data were presented. In contrast, 100-300 passes were found to cause yield losses of 6.7-29 metric T/Ha (3-13 T/A) of forage crops (timothy, grass, clover, alfalfa), despite near-record snowfalls (275).

In other studies (268,269) the physical structure of the soil was significiently altered by snowmobile traffic. The new soil environment may harm some plants and soil organisms, not affect others, and benefit others. The impact varies with the severity of the winter, snow depth, intensity of snowmobile traffic and plant lability toward cold temperatures or physical contact. Plants with bulbs or tubers seem to be harmed; plants with smaller storage organs are not affected. Growth and reproduction of early spring flowers is inhibited. Alfalfa is winterkilled by snowmobiling because it freezes out, but grasses and broad-leaved weeds are not damaged and may even be benefited. Some species whose germination is stimulated by cold may also benefit.

Woody plants were particularly vulnerable to physical damage by snowmobiles. Deciduous trees, tall shrubs and young conifers are readily damaged when snow cover is meager, but low shrubs are unaffected. Species that form sucker shoots remained undamaged or increased during a 2-year period. These effects may not endure, since disease or eventual failure of large root systems to maintain themselves may still develop.

On the basis of these observations, snowmobiling could be used as an environmentally acceptable method for vegetation control in some areas. Approximately 50 passes per year suffice to keep unwanted vegetation down. This type of control is preferable to spraying of herbicides in some locations, since many plants used for food by wildlife and man are not destroyed.

Effects of winter injury or mechanical injury may not always show up quickly (268): white spruce sapling mortality may be delayed more than one year. No observations have yet been made of long-term effects of snowmobiling on vegetation. Snowmobiling delays the spring activity of soil microorganisms because soil temperatures beneath compacted snow is significantly lower than those under undistrubed snow cover (270). However, heterotrophic organisms revive quickly as soil temperatures warm up. Soil temperatures under areas of heavy and moderate usage have higher temperatures probably due to drifting of snow into the tracks after each compaction.

Possibly beneficial effects of snowmobiles on soil were reported in other studies (143). Compaction on four types of trails decreased snow depth, increased snow water content and delayed snowmelt. Increased snow water content was beneficial in areas where evaporation of snow exceeded water infiltration rates. Persistent snow cover also protected steep, unvegetated roads until after the peak of thaw runoff had passed, thereby reducing erosion.

Significant snowmobile damage to hardwood saplings and planted pines was also found in Canada (198): 78% of saplings on a woodland trail were damaged by a single passage, while all vegetation above the compacted snow was mechanically eradicated. Seedlings and golf greens are also particularly vulnerable to damage by snowmobiles (37).

These findings indicate that a practice observed recently of drag racing of snowmobiles in summer (238) could have severe or disasterous effects on soil and vegetation and should be discouraged.

Published information on various aspects of the impact of snowmobiles on the environment is summarized in a recent bibliography (170). The current practice of using part of snowmobile registration fees for trail construction and maintenance will help reduce adverse environmental impact of this activity.

Engine emissions from snowmobiles can convey pollutants both directly and indirectly to the aquatic environment. Direct influx results from operation of machines on the frozen surfaces of lakes when pollutants are deposited on the ice or snowcover. Heavy snowmobile traffic on a frozen lake deposited measurable amounts of lead (30-80 ppb) and oil (2 ppm) on surface ice (205). Indirect pollutant influx results from atmospheric fallout on land or water, from deposition on snowscapes and from precipitation. Pollutants in the snowcover move into lakes and streams during the spring thaw. Engine emissions include oil, hydrocarbons, CO, NO_x, SO_x and particulate matter. The percentage that snowmobile engines contribute to the total emissions from all sources or of mobile sources is given in Table 10. Estimated values of the national emissions of snowmobiles is given in Table 11.

All of these sources are relatively insignificant compared to other sources, particularly automobiles (7). However, it is noteworthy that many lakes in the Basin which once received engine emissions only during the boating season are now receiving snowmobile engine emissions during

TABLE 10

Comparison of snowmobile emission estimates with EPA Nationwide air pollutant inventory data (135)

	1970 EPA inventory data 10^6 tons/yr	(Revised)	Snowmobile estimates as % of	
Pollutant	All sources	Mobile sources	All sources	Mobile sources
HC	27.3	15.2	0.223	0.401
CO	100.7	78.1	0.094	0.121
NO_x	22.1	11.0	0.004	0.009
Particulate	33.4	1.0	0.008	0.270
SO_x	25.5	0.9	0.0003	0.009

Conversion factor: 1 ton = 0.91 metric ton

TABLE 11

Estimated national emissions impact of snowmobiles (135)

Pollutant	g/unit year	Tons emitted per year
HC	37,800	60,900
CO	58,700	94,600
NO_x	600	967
RCHO	552	890
Particulate	1,670	2,700
*SO_x	51	82

*Calculated on the basis of fuel consumption and sulfur content of 0.043 percent by weight

Conversion factor: 1 ton = 0.91 metric ton

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winter, when the lakes are frozen, and no biological activity is occurring which could destroy the pollutants. Such winter emissions could have a more serious impact than higher summer loads.

3.4.5 Off-road Vehicles

An off-road recreation vehicle (ORRV) is defined by the U.S. Dept. of the Interior (USDI) as any motorized vehicle capable of travel on or immediately over land, water, snow, ice, marsh, swampland, or other natural terrain without benefit of a road or trail (254).

The recent rapid growth of ORRV use has aroused a growing conflict among conservationists, recreationists, developers and public land managers. Controversies arise from the increasing demand for lands for ORRV use and concern for the possible impact of these vehicles on the environment. The ORRV industry is one of the fastest growing in America; this is reflected in the number of sales of motorcycles and minibikes. In 1970 alone, about 730,000 motorcycles and nearly as many minicycles were sold (72). Combined sales of such vehicles had averaged only 125,000 for the years 1960-62 (249). Sales are expected to climb to 850,000 units by 1980, with registrations rising from 2.7 million in 1970 to some 5 million in 1980.

Development of the market for the more expensive all-terrain vehicles (ATVs) sales took place more slowly: sales did not exceed 2,000 units until 1968. Shipments to the U.S. and Canada hit a peak in 1969 at about 15,000 units and fell to 12,000 units in 1970. U.S. sales were 12,000 units in 1969 and 9,000 in 1970. However, forecasts of the number of sales of ATVs for 1980 are placed at about 60,000 units annually (25).

A presidential report in February 1972 quoted a USDI study showing that there were approximately 5 million ORRVs in the United States (12). These include motorcycles, minibikes, trail bikes, snowmobiles, dune and swamp buggies, ATVs, airboats, hovercraft and others. Snowmobiles are treated separately in this report (see Section 3.4.4). The number of ORRVs, excluding snowmobiles in the U.S. in 1972 is therefore placed around 3.5 million (1.5 million snowmobiles in 1972). Approximately 15% of the national population resides in the Great Lakes Basin. Assuming uniform distribution of ORRVs amoung the population the number in the Basin would be placed at approximately 525,000. However, the greater popularity of lightweight ORRVs in more arid parts of the country suggests a more reasonable estimate of 300,000-400,000 ORRVs in the Basin. These figures represent 8.6 to 11.4% of the total ORRVs in the U.S. ATVs are more popular in the Basin than in other parts of the country because of their use in hunting and fishing.

According to actual counts in Wisconsin, use of ORRVs constituted approximately 0.3% of the total 1970 recreation occasions (39). Because of the suspected negative environmental impact associated with the large numbers of ORRVs now in use, President Nixon issued an executive order in February, 1972, concerning their use on public lands. The objective of this order was ". . . to establish policies and provide for procedures that will ensure that the use of off-road vehicles on public lands will be controlled and directed so as to protect the resources of those lands . . . and to minimize conflicts among the various users of those lands" (11644). This order applies equally to all ORRVs, but vehicles other than snowmobiles pose special problems because wheeled vehicles make direct contact with the soil rather than a protective covering of snow.

A 1968 study (249) showed substantial damage to soil and vegetation by motorcycles, dune buggies and four-wheel drive vehicles (FWDVs). Although the study area was the California Desert, the findings maybe transferable to the Great Lakes Basin situation. Hillclimbing areas under continual use for five years were more adversely affected than any other sites, owing to steep slopes and heavier use (compared to cross country trails). Soils in these areas were more compacted, often enough to prevent seed germination, thus eliminating vegetation. Up to 90% denudation took place in some areas.

A 1970 case study on the environmental impacts of two-wheeled and four-wheeled ORRVs was also conducted in California (189). Cycle use of the study area began around 1960. By 1967-1969, cycle use had resulted in up to 60% loss of vegetation, 486 Ha (1,200 A) intensive use area. Other areas were completely denuded by hill climbing. In wooded areas, cycle trails cut ruts at the edges of streams. These ruts eventually broke down stream banks, muddied the water and speeded up erosion. In another study (251), motorcycle use caused erosion problems in unstable soils until a system of trails was laid.

One positive effect of two-wheeled ORRVs was in keeping firebreaks that had been bulldozed through chaparral clear by constant use. These would quickly revegetate unless they were popular trails for cyclists.

A soil loss of 91 m^3/Ha (48 yd^3/A) was estimated from a heavily used 1.4 Ha (3.5 A) hill climbing area (189). However, trail scooters used at reasonable speeds and on resonable grades were suspected to cause less impact on trails than horses (251).

With the possible exception of specific cycle hill-climbing areas, all of the environmental impacts of two-wheeled vehicles was also caused by FWDVs (187).

Driving in the dunes of the Back Bay National Wildlife Refuge increased the rate of dune erosion by killing what little vegetation was present (251). It has been suggested that FWDVs and motorbikes cause five hazards (251). Other studies refer qualitatively to erosion caused by ATVs (37,171,251). However, in Florida, ATV tracks were quickly obscured because of favorable climatic conditions and vegetative types conducive to rapid regeneration (251). This report warned, however, that long range impacts might occur.

Published information on ORRVs and their environmental impact is summarized in a recent bibliography (170).

The accelerated erosion caused by ORRV use can cause impairment of water quality by increased sedimentation. In addition, engine emissions from some ORRVs can also contribute pollutants to aquatic environments. Direct inputs originate from operation of ATVs, hovercraft, amphibious vehicles and swamp buggies over water surfaces, but loads are normally small in comparison with regular powerboats. Further, minor inputs to

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waters from ORRVs used on land can occur through atmospheric fallout and allied mechanisms.

ORRV engine exhaust contains hydrocarbons, CO, NO_x, SO_x and particulate matter. The total amount of all ORRV engine emissions is not known. However, estimates of the atmospheric emissions for motorcycles and for small engines used for recreation have been made (see Table 12); these are insignificant compared to other engine sources.

The main hazard to water quality associated with ORRVs is therefore accelerated soil erosion. This factor can be controlled through proper trail construction and maintenance. Some sensationalism used in advertizing ORRVs in magazines and television is often counterproductive toward educating individuals to use these vehicles responsibly and with proper concern for the environment.

3.4.6 Hunting

The popularity of hunting in the region is reflected by the fact that the sport accounts for 24% of the non-summer activities in part of the Great Lakes Basin (Wisconsin) (39). Throughout the Basin, land for hunting is largely publicly owned. The annual recreation occasions for hunting is expected to increase by 24-26% from 1970-1990 in Wisconsin (35,39). No data was available for other states within the Basin. However, U.S. duck stamp sales--an indication of the number of hunters--was down 15% in 1972 versus 1971 and 3% in 1971 versus 1970. Waterfowl bagged has also decreased from 1970-1972 (67,68). Nevertheless, overall hunting recreation occasions are expected to increase, but the facilities, land available and wildfowl populations necessary to satisfy the demand are lessening. Urbanization, intensive agriculture, marsh drainage and other land use practices have reduced the land available for hunting and for game production. Of specific concern are the inadvertant game losses caused by the current use of leadshot in wildfowl hunting.

Water pollution related to hunting can come from several sources. Two main pollutants are solid and liquid wastes. Solid waste generation

TABLE 12

Atmospheric emissions of ORRV engines as percentages of total and mobile engine emissions

	Hydrocarbons	CO	NO_x	SO_x	Particulates
Motorcycle Estimates (132)					
National total of all sources	0.524	0.431	0.0176	0.0018	0.0132
Mobile source emissions	0.933	0.571	0.0342	0.06	0.479
Small Engine (133)					
National total of all sources	0.389	0.761	0.0573	0.0044	0.013
Mobile source emissions	0.692	1.01	0.111	0.15	0.46
Small Engines-Recreational Application (2.8% of Total of Small Engines) (134)					
National total of all sources	0.011	0.021	0.002	0.0001	0.0004
Mobile source emissions	0.019	0.028	0.003	0.004	0.013

rates at cabins used for overnight hunting is about 0.7 kg (1.5 lb) per person per day (234). Soil erosion may also result when four-wheel drive or other off-road vehicles are used on unsuitable terrain for hunting.

An important source of pollution is the lead used in scattershot. As such, the lead from the shot probably has only a minor or insignificant effect on water quality, but it does have a significant effect on waterfowl populations. Waterfowl hunting usually produces heavy concentrations of hunters in locations frequented by wildfowl. High rates of shooting and concentrated use of an area over a period of years can result in serious lead poisoning to waterfowl. Massive waterfowl die-offs due to lead poisoning have been studied since 1901 (52,81,126, 156,174,207,272). History of work on this problem is summarized briefly in Table 13. The levels of toxicity in some flyways (15) are three times greater than previously estimated by Bellrose in 1959 (40,41).

Using 20 μg/g body weight (20 ppm) as a danger level for lead, the USDI Bureau of Sport Fisheries and Wildlife found this level exceeded in over 16% of Pacific Flyway birds, over 13% of Mississippi Flyway birds, over 17% of Atlantic Flyway birds, and about 5% of Central Flyway Birds (15) (see Table 14).

The annual loss of 2-3 million ducks from lead poisoning amounts to 20-30% of the average harvest of 10 million ducks (40,41), and equals or exceeds the entire harvest in some flyways (253). Information for mallards in Minnesota, Illinois and Michigan indicated elevated lead levels of 13%, 11% and 13%, respectively (79).

There appears to be a north-south gradient in the amount of lead salts detected in mallard wingbones (cf. Table 14). Immature mallards ingest some pellets on northern breeding grounds, but the majority of intake occurs during migration southward. There is some evidence that a significant amount of ingested lead comes from shot discharged during the current waterfowl season (79). If this is true, an immediate

TABLE 13

Milestones in the study of lead poisoning in waterfowl (Data from 231)

Problem known for over 100 years . . . . Early 1900's biologists documented concern and predicted it would worsen . . . . 1948-Die-off in Illinois precipitated cooperative study between Olin Mathieson and Illinois Natural History Survey to evaluate waterfowl losses, investigate substitutes for lead shot, and determine physiological effects . . . . 1959-his work culminated in Bellrose report focusing attention on . . . . 1962-Mississippi Flyway Planning Committee resolved to reduce waste of waterfowl . . . . 1964-Iron shot tested at Nilo Farms on live ducks under shooting preserve conditions . . . . 1965-Mississippi Flyway Council publication on "Wasted Waterfowl" . . . . 1966-SAAMI formed non-toxic shot committee and supplied $100,000 for substitute shot investigation . . . . 1965-67-Bureau tested substitute shot candidates; iron seemed to be best . . . . 1968-Iron shot tested on live ducks under controlled conditions at Patuxent Wildlife Research Center . . . . 1970-International Association of Game and Fish Commissioners requested Bureau of Sport Fisheries and Wildlife to begin transition to non-toxic shot for migratory bird hunting and to prohibit use of toxic shot for waterfowl before the 1973 season . . . . 1971-Iron shot tested under field conditions at Remington Farms . . . . 1972-SAAMI suggests steel shot field test by U.S. Bureau of Sport Fisheries and Wildlife (BSFW).

TABLE 14

Levels of lead salts in wingbones of flyway ducks (Data from 79)

		Percent of Ducks Tested		
Flyway	Range ug/g	0.5-10 ug/g	10-20 ug/g	>20 ug/g
Atlantic	<0.5 - 164	14	69	17
Mississippi	<0.5 - 413	49	38	13
Central	<0.5 - 86	67	28	5
Pacific	<0.5 - 400	53	31	16

0.5 - 10 ug/g - Low levels - normal or near normal

10 - 20 ug/g - Moderate levels - sublethal, some mortality possibly occurring, possible effects on reproduction and susceptibility to hunting and predation

>20 ug/g - Elevated - significant mortality due to direct lead poisoning occurring

Conversion factor: ug/g = ppm

beneficial response would result if an effective non-toxic shot were introduced.

The densities of spent pellets in heavily hunted marshes and lake bottoms can range from 14,826-296,520/Ha (6,000-120,000/A) in upper layers of sediment (231). Depending on detritus settlement and sedimentation rates, the accessibility of pellets to many species of waterfowl varies. Some species (e.g. mallards) tend to dig into mucks and muds when feeding, making pellet ingestion likely (231). However, a single pellet can often poison a bird (40,41).

Ducks, geese and swans feeding in heavily hunted marshes and shallow lakes swallow lead pellets along with seeds and grit. The shot enters the gizzard along with food and small pebbles and is retained there, eventually being dissolved by digestive acids and absorbed into the bloodstream. Several organs deteriorate, including the liver, kidneys and gizzard (126). This results in anemia and muscular disorders that cause higher susceptibility to other forms of mortality in addition to death from intoxication by lead itself. The nervous system is affected, resulting in partial paralysis of the extremities (wings) (231). Some birds eventually starve to death (15). In addition, the ducks mobility is reduced, with effects on reproduction and susceptibility to hunting and predation (40,41).

Lead poisoning also occurs in geese and swans, but despite this, the goose population appears to be increasing. Further discussion of these topics and short literature reviews are given in recent publications (241,242).

The best non-toxic substitute for lead shot available at present is made from iron or soft steel. The main disadvantage with the harder iron pellets is increased gun barrel damage (162,253). The effective range is shorter 36.6 meters-40 yd for iron, 45.7 meters-50 yd for lead because of the lower density of iron 7.86 g/cm^3 (0.285 lb/in^3) versus 11.3 g/cm^3 (0.409 lb/in^3) for lead (162). Reductions in the number of deaths due to lead poisoning brought about by substitution of iron shot could be offset by deaths resulting from crippling, because of the lower efficiency (162). Differences of opinion exist concerning the extent to which iron shot might increase crippling losses; one estimate predicts an increase of 3 million crippling-deaths (219). However, skillful hunters would presumably soon learn to adapt to the shorter effective range of steel shot and avoid shooting at ducks beyond the lethal range.

A mixture of powdered lead and powdered iron has recently been tested (150), which may eliminate the problems of range, toxicity, and barrel wear. The composite pellets did not damage gun barrels and had almost as long a range as lead shot (150). The pellets disintegrate on hitting water or while lying in sediments, so that chances of ingestion and deposition in wildfowl gizzards is circumvented. However, these pellets would still increase the lead content of lake sediments and may be undesirable from this standpoint.

An indirect source of water pollution associated with hunting may arise from duck farms used for raising ducks for hunting in private areas. Measurements suggest that ducks and geese droppings can be a significant source of water pollution by fecal wastes (110,157,202). Depending upon species, a goose produces 60-175 g/day (0.13-0.4 lb/day) of manure with 2.2% N, 1% P_2O_5 and 2% K_2O (day weight basis). Accumulations of wildfowl droppings at roosts on small inland lakes may materially affect the trophic state of the water (157). Ducks excrete 54-68 g (0.12-0.15 lb) of dry solids per day (202). Duck droppings were estimated to contribute 14.3 kg/Ha (12.8 lb/A) of N and 19.2 kg/Ha (17.1 lb/A) of P to a lake in Illinois (202). The high N(28-39 mg/l,ppm), BOD_5(60-380 mg/l,ppm) suspended solids (80-1,800 mg/l,ppm) and coliform counts (1-46 x 10^6/100 ml), in waters near duckfarms dictate that wastes from these areas must be treated (110). Similar waste loads presumably also occur at gamefarms for raising pheasants.

3.4.7 Vacation Homes and Resorts

For many people, vacation homes provide an ideal base for participation in numerous forms of outdoor recreation, for others, their value lies simply in providing a retreat from everyday life. Nowadays more and more people are buying or renting vacation homes, or visiting remote resort areas to stay and relax for a few days or weeks in order to recover from the stress of modern living.

The exact number of vacation homes in the Basin is unknown; only estimates or incomplete counts for some parts of the Basin are available (see Table 15). There is also considerable disagreement among the sources of these data. This may reflect whether cottages or cabins offered for rent on a seasonal basis have been included in the counts. In any case, the number of private one-family dwellings used as vacation homes is extensively supplemented by large numbers of multi-unit complexes of motels and lodges.

The possible impact of all these summer homes, cottages, cabins and complexes on water quality cannot be overlooked. The main impact is likely to come from their domestic sewage wastes. The great majority of vacation residences are located far from municipal sewage collection systems, and therefore have their own individual on-site disposal systems (239). These are mainly septic tanks coupled with soil absorption beds for clarifying and purifying the tank effluent (16,22). Occasionally holding tanks are used which are pumped out periodically and the contents are disposed of on approved land disposal sites or discharged into municipal treatment plants. High operating costs discourage this option (239). Cesspools are generally prohibited.

The number of private domestic sewage treatment and disposal systems in the Basin must be large, but is unknown. Since only 83% of the 1970 Basin population of ca. 35 million or 76% of its effective recreational population of 30.25 million lived in standard metropolitan statistical areas (SMSAs) (i.e. large urban areas) as many as 6-7 million people in the Basin may live in permanent residences in unsewered areas. Vacation homes and resorts are presumably used mainly by people from SMSAs, so that the number of unsewered dwellings increases substantially during the recreational season.

The directness of the impact on water quality of septic systems

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TABLE 15

Vacation homes by lake basin within the Great Lakes system

Basin	Actual counts*	Estimates
Lake Superior	20,891 [1970] (44)	
Lake Michigan	83,637 [1970] Wisconsin and Michigan only; Illinois and Indiana not included (44)	>25,000 in Lake Michigan watershed of Wisconsin [1961]; 70,000-80,000 in entire Basin [1965] (124)
Lake Huron	27,838 [1970] (44)	44,000 [1969] (124) 44,275 [1965] (63)
Lake Erie	8,860 [1970] Michigan only; Ohio and Pennsylvania not included (44)	21,000 [1970] (44, 124)
Lake Ontario		37,500 [1960] (124)

*Dates in brackets; references in parentheses associated with vacation homes or resorts is presumably greater than that of systems attached to permanent dwellings because recreational homes are normally close to lakes and streams. However, this effect is counteracted by the fact that most homes are used only for a portion of the year, usually the summer and fall, and that during this period the biological processes in the soil and water which help purify septic tank effluent are more active.

Normally a septic tank/soil seepage bed sewage disposal system does an efficient job of removing the bulk of the BOD, COD, P, N and bacterial loads present in domestic sewage. However, under some circumstances individual sewage treatment systems can become a major source of pollution to both surface and ground waters (34,127,204,271). Improper design, construction, or location can lead to failure of the system or inadequate purification of the septic tank effluent, resulting in pollution problems. Disposal systems can fail in several ways (178). For example, the site location may be unsuitable (42,51,192): the soil may be highly impermeable to sewage effluent, or hard pans may develop through destruction of the soil structure by ponding or puddling. Untreated effluent may then ooze out and contaminate surface waters. Again, the depth of the soil to the bedrock, especially creviced bedrock, or to high water tables may be insufficient to purify the liquid sewage. In such instances contamination of the ground water occurs. Location of septic systems in areas of seasonal flooding also created pollution problems following inundation. In other instances, especially on lakeshores, the slope of the land may be so steep that the liquid effuent surfaces, creating local health and odor problems and contaminating the lake when washed in with precipitation runoff. Even well designed septic systems built on permeable soils can fail: the seepage beds no longer permit liquid effluent infiltration at an adequate rate because an impermeable layer is formed in the soil under anaerobic conditions. This phenomenon is called clogging or crusting (85,86,177,179). Clogging and crusting may be due to accumulation of solids filtered from septic tank effluent at the interface of gravel and soil in the seepage bed, and to microbial proliferation in the upper few inches of the soil below the bed (175). Both effects result in an accumulation of organic matter that plugs the soil pores (155). The hydraulic effects of the crusts greatly affect seepage and cause surfacing of unpurified effluent (22). At present, the only remedy known for the clogging/crusting problem is to rest the system and allow it to aerate (49,179). It has been suggested that, as a preventive measure, on-site disposal systems should be provided with double seepage beds, so that one could be kept in the aerobic recovery stage while the other is being used (47). Some solutions have also been offered for sites limited by soil conditions: for slowly permeable soils, a very large seepage bed can be used or a prepurification sandy soil mound can be constructed on top of the native soil; the mound functions partly to purify the effluent and partly to distribute it over a wider area so as to make absorption possible without as great a danger of clogging (22,47,50).

Even with properly-functioning septic systems, pollution of groundwater by NO_3 is a constant hazard (95,176,188,211,261,262). Biological decomposition of waste organics in an anaerobic environment of the septic tank produces large amounts of NH_4 which pass over in solution in the tank effluent to the seepage bed. Nitrifying bacteria in the aerated soil of a properly functioning system rapidly oxidizes NH_4 to NO_3. As a readily soluble anion, NO_3 is not absorbed or retained by the negatively charged clay particles in the soil seepage bed but moves freely through the medium, entering the ground water in the vicinity. Drinking water drawn from wells too close to septic disposal systems may contain high NO_3 concentrations, possibly over the 10 mg-N/l safety limit set in 1962 by the U.S. Public Health Service. Overdoses of NO_3 seldom occur, but may affect infants with an illness known as methemoglobinemia. In addition NO_3 entering the aquifer can also lead to accelerated eutrophication of surface waters (22).

The average person produces about 8.2 kg (18 lb) of N per year (22,261). Of this, 3.6-5.4 kg (8-12 lb) is of fecal origin (176).

Thus, NO_3 contributions to the groundwater from an average family of 4 is almost 32 kg (70 lb) of N per year, since only a minor amount is transormed into elemental N by denitrification in lower horizons of the soil. The amount of NO_3 reaching the groundwater averages 2.24 kg/Ha/yr (2lb/A/yr) of N (22,262). The greatest potential hazard of NO_3 pollution is local contamination of a shallow, downgradient well used as a water supply, especially where there is a concentration of many small individual lots, each with a septic tank system. If such lots are close to lakes or streams, eutrophication--excessive nutrient enrichment--may be accelerated due to the movement of NO_3 in the groundwater to the surface waters.

The efficiency of an average septic tank in reducing wastes in raw sewage is indicated in Table 16. However, sludge gradually builds up inside the tank, so that it must be pumped out every few years. Otherwise the accumulated solids fill the tank and spill over into the seepage bed and quickly clog the soil pores, causing the system to fail. A good soil seepage bed purifies the partially clarified effluent from the tank, effectively removing all the suspended solids, BOD, COD, P, bacteria and viruses (22,86,177). Even detergents are effectively removed (128,216). Systems perform well even under adverse climatic conditions (141). The efficiency of the soil purification system has been frequently demonstrated with soil columns under laboratory conditions (127,155,183,184,209). P is normally retained by absorption on hydrous Fe or Al oxides in acidic soils, or as insoluble alkaline earth phosphates in clays and loams. However, losses of P to the groundwater can occur through highly porous sandy soils (95,127), but this situation is readily remedied by incorporating limestone or dolomite into the seepage bed to retain this nutrient as insoluble calcium phosphate. It takes many years before the exchange capacity is exhausted and breakthrough of P may occur. However, P losses could be occurring in older systems that have been functioning for many decades. This could be especially true with systems that were installed at sites now considered unsuitable

TABLE 16

Average concentrations (mg/l or ppm) of raw and septic tank wastewaters (22)

Wastewater	Biochemical Oxygen Demand	Suspended Solids	Total Nitrogen	Phosphorus	Fecal Coliforms
Raw Waste	350	400	80		
Septic Tank Effluent	150	140	50	20	1,200,000/100ml

under the present health codes (22). Percolation through peat offers another method of removal (210).

Bacteria and viruses are normally completely retained, even by porous, sandy soil (220). The approximate count of coliform density for household raw sewage ranges from 10^8 to 10^9 organisms per 100 ml, for septic tank effluent the count is 3×10^7 to 3×10^8 per 100 ml, and for septic tanks subsurface sand filters 3×10^4 to 3×10^5 per 100 ml (239). It is possible for losses to occur through shallow soils above creviced bedrock, and contamination has occasionally been observed (182). However, under normal conditions the majority of bacteria and viruses are killed in the first few inches below the gravel-soil interface (51).

Site location is of prime importance for the proper functioning of on-site disposal systems. At present, the soil percolation test is the main criterion used for determining where a disposal system can be placed (46,48,84). However, this criterion is no longer considered adequate: the percolation tests exhibit tremendous variability, influenced by a complex association of soil and environmental factors. Soil maps, the geology of the area and water table maps (146,263) should also be used as guides before permits are issued. The spacing of systems from wells for domestic water and the distance of systems from lakes or streams should be rigidly controlled to avoid pollution of ground and surface waters. Lately efforts have been made to develop alternative on-site treatment systems for domestic sewage; these are mainly based on mechanical devices designed to promote aerobic fermentation of the wastes or to prefilter tank effluents, in order to reduce the suspended solids and BOD loads reaching the seepage bed (165,201, 209). These measures are intended to retard clogging, and to extend the life and increase the efficiency of the seepage bed. However, they are more costly than the straightforward system and require more maintenance, but their use can be justified in certain problem areas.

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3.4.8 Camping

Camping in the Basin is mainly a summer activity and accounts for approximately 1.4% of the total annual recreation day requirements for all activities (124). The total annual recreation day requirement is expected to increase by a factor of 4.1 from 8.2 million in 1970 to 33.5 million in 2020 (124). Thus, in 2020 camping will represent 1.8% of the projected total annual recreation day requirements. Current growth in camping activity is reflected in a 34% increase in sales of camper vehicles in 1972 over the 1971 figure (25).

Campgrounds in the Basin are of three kinds: overnight-transient, vacation and primitive. Overnight campgrounds have parking for recreational vehicles, basic sanitary facilities, utilities and are near highways. Vacation campgrounds are favored by families and provide recreation opportunities on or near the campsite; they are usually located close to abundant supplies of recreational resources and facilities. Primitive sites have no access for automobiles and provide only minimum development in the form of cleaned tent sites, fire rings and possibly water and latrine facilities. Considerable areas of completely undeveloped public and private lands are open for remote camping.

Demands for intensively developed campgrounds are increasing. Ideally equipped campgrounds for "roughing it" now include electricity, running water, flush toilets, showers, dumping stations, concrete parking pads, laundromats and sewer hookups (35). Lists of campgrounds and their facilities are available for all the Great Lakes States (24). The advantages of "the comforts of home" may be important factors in the future as the demand for environmental quality and more stringent pollution standards are increased.

Camping can affect water quality through improper site design, overuse of sanitary facilities and inadequate treatment of wastes. Both surface and groundwaters can be affected. Campers generate solid waste at a rate of 0.57 kg/person/day (1.26 lb/person/day) composed of 37% food wastes, 30% other combustibles and 33% noncombustibles (234). Provisions for proper disposal must be made to avoid water pollution by litter or dumping.

Intensive use and inadequate management of camping areas can have detrimental effects on soil and vegetation often resulting in increased erosion (167). Significant effects include compaction of surface soil and destruction of the protective ground cover vegetation. In detailed measurements on typical campsites, surface soil loss--due to sheet erosion--amounted to 5-8 cm (2-3 in) on the average or as much as 23 cm (9 in) abused areas (226). Surface soil compaction with increases in bulk density of 0.21-0.29, and the formation of an "erosion pavement" reduced infiltration thereby causing rapid runoff. Loss of soil organic matter through direct erosion produced lower permanent wilting percentages and field capacities. The lower organic matter content of the surface soil also lowered infiltration rates and restricted soil moisture recharge, with detrimental effects on certain plant species throughout the season. These spiraling effects result in the high erosion rates observed.

Soil losses also have been measured in numerous primitive wilderness campsites in the Superior National Forest along the Boundary Waters Canoe trail (210). These areas present special problems. Because of inaccessibility and constraints placed upon measures permissible to control soil loss--only "native" materials can be used to preserve the "wilderness" features of the sites--high rates of erosion occur. Losses of 9-11.2 metric T/Ha/yr (4-5 T/A/yr) are found for some fragile soils at intensely used sites. The bulk of the loss occurs by rill and sheet erosion; about 10% is gully erosion. Despite the high rates, the impact on the lake is insignificant, because the sites are so small, generally less than 0.2 Ha (0.5 A). Damage to the resource is as important as the effect of erosion on water quality. Protection of the sites can only be achieved by careful management.

Management of human wastes is also a problem at wilderness campsites. Treatment facilities are not compatible with the concept of "wilderness", and sewage can affect ground and lakewater near heavily used sites. Latrines or pit toilets are provided at some sites, detention systems that are periodically emptied at others. It has recently been found that peat proves to be an acceptable efficient absorbing medium in latrines. Phosphorus losses from peat-lined latrines were lower than native values (210). To reduce erosion and sewage problems in wilderness camping areas, campsites are placed at least 30.5 meters (100 ft) from the lake, and latrines even farther away (210).

Good management practices and adequate maintenance can also control erosion at highly developed sites intended for intensive use. Seeding of problem soil areas with suitable resistant plant species for ground cover and planting of shrubbery or thorned bushes in "off-limits" areas can mitigate adverse effects of human traffic. With adequate investment, pollution loads from campsites can be reduced to insignificant levels.

3.4.9 Fishing

Next to swimming, fishing in the Great Lakes Basin is considered the second most popular water-dependent activity (62,65), but the total annual recreation day requirement has not been determined. Comparison may be made to Wisconsin where fishing accounts for 11.5% of the total summer activities (39). Details concerning sport fishing for each planning sub-area in each lake basin in the Great Lakes System have been reported (62-66).

Great Lakes waters, inland lakes, rivers, ponds, trout streams and warmwater creeks are all used for recreational fishing in the Basin. In contrast to other outdoor activities, the needs of the fish rather than of the recreationist dictate water quality requirements. However, some phenomena associated with fishing can cause inputs of pollutants into fishing waters.

Inputs can be of several different types. Powerboats used for fishing can contribute fuel, exhaust and sewage wastes to surface waters. These inputs have been discussed under powerboating (Section 3.4.3). Although no measured data are available, some erosion of stream and river banks and littering caused by fishermen occurs sporadically. A potential source of water pollution is developing from the rapidly growing sport of ice-fishing. The surge in popularity of this sport is evidenced by the large number of participants: as many as 30,000 per week on Lake Winnebago, Wisconsin (13). Most of these fishermen drive onto the frozen lake by snowmobile, car, truck or van. Over 2,500 vehicles have been counted at a single time on Lake Houghton, Michigan (205). Exhaust emissions from these vehicles condense on the ice, contaminating it with lead and oil (205). Besides vehicles, many fishermen take along outhouses furnished with chemical toilets or "thunder mugs"--pots with disposable plastic liners. Federal law prohibits disposal of boat sewage wastes into navigable waters, but disposal of sewage wastes from ice fishing shanties is not yet regulated. In addition, many of the fishermen use liberal injections of anti-freeze (ethylene glycol) to prevent the holes they have bored in the ice from freezing over. No figures are available as to total amounts which may be added to the water.

Fish hatcheries are also considered to be potential sources of pollution, although this is felt not to be a serious problem (71,94). Fish from hatcheries are used for put-and-take fisheries, restocking and restoration of depleted fish populations. Feeding and cleaning of the raceways (where the fish are grown) contribute minor pollution loads. At several hatcheries studied, cleaning of the raceway contributed a BOD load of 1.2-2.5 kg (2.7-5.4 lb) and a COD of 3.1-5.6 kg (6.8-12.3 lb) (70). However, the total P, NH_4, NO_3 and NO_2 levels measured were only slightly higher than those of the incoming waters; these levels were felt not to contribute to stream degradation (145,227). Periodic flooding of a marsh for northern pike spawning slightly increased the influx of P into a Michigan inland lake (9.5×10^{-6} kg/m^3, 0.026 lb/acre-foot net gain of P), but reduced the input of nitrogen (8.8×10^{-6} kg/m^3, 0.024 lb/acre-foot retained by marsh); these effects were considered insignificant (199).

Improper design and construction of hatcheries can result in sludge deposits in the stream (94). However, these problems could be diminished by use of settling basins (70).

There is often a high mortality (up to 65%) rate among game fish once the stock has been released to open waters, owing to the sensitivity of the fish to minor temperature differences and other physiological factors. Fish carcasses can occasionally become a source of esthetic pollution. Overstocking can also become a problem, aggravating mortality rates because of lack of sufficient food. The latter problem often can be solved easily by allowing a larger harvest to be taken from overstocked waters, either by decreasing the legal size limit, or permitting normally outlawed angling methods such as snagging or gaffing. Since fishing is a well organized sport, requiring licensing, any pollution inputs associated with the activity can probably be largely controlled by appropriate management practices and regulations.

3.4.10 Golfing

Opportunities for golfing in the Great Lakes Basin are offered at both public and private golf courses with a combined area of 27,431 Ha (67,730 A). Golfing accounts for approximately 2.5% of total summer activities placing it in a low activity group. Annual requirements for golfing in terms of recreation days are expected to increase more than threefold from 13 million in 1970 to 47.6 million in 2020 (124). Since courses currently available are being used to or beyond ideal capacity, land requirements for golfing are likewise expected to increase corresponding to demands (124).

Potential water pollutants originate from golf courses because large amounts of pesticides and fertilizers are used for grounds maintenance. Soil erosion, especially during the establishment of vegetation, accounts for much of the fertilizer and pesticide loss. Practices should be adopted to minimize soil erosion during construction and turfgrass establishment (90).

On golf courses, greens receive the most intensive applications of pesticides and fertilizers. Greens constitute only about 1.5% of the total golf course area, but the permeable soil structure of greens, heavy applications of water and subsurface drainage make them major sources of pollution. One study showed that more than 50% of the total N applied as soluble fertilizer may be washed through greens in 2 weeks (90). Up to 300 mg/l, ppm of NO^3 occurs in green leachate within days of fertilizing with 100/kg/Ha (89 lb/A) of N. Losses are lower and more protracted if organic N fertilizers are used, even at equivalent N loadings (90). Runoff from a golf course contained BOD loads of 13 kg/Ha/yr (12 lb/A/yr), 67 kg/Ha/yr (60 lb/A/yr) of COD and 1.2 kg/Ha/yr (1.1 lb/A/yr) of soluble orthophosphate. Total solids ammounted to 739 kg/Ha/yr (660 lb/A/yr) (101). This information is presented in Table 17.

Pesticides, including herbicides, insecticides and fungicides are also lost through leaching and runoff. Pesticides containing Hg and As have been studied (90) to determine leaching losses, plant uptake and residue hazards on golfgreens and fairways. Losses by leaching depend on soil texture; leaching was high through sandy profiles but negligible in the presence of 5% clay loam.

Arsenic is usually applied as tricalcium arsenate or disodium meta-arsenate at the rate of about 1-11 kg/Ha (1-10 lb/A). Like P, As is rapidly immobilized by all except sandy soils. Normally As remains in the top 5 cm (2 in) of soil, very little is leached below the root zone; thus, arsenicals remain at the site of application unless removed along with grass clippings which have accumulated As during growth. Disposal of these clippings is best accomplished by spreading them on the surface or incorporating them into the soil (90).

Mercury fungicides are also fixed in the surface layer of soil; unless excessively high rates are applied, only trace amounts are leached through the profile (90). However, organically-bound Hg has been found to contribute significant pollution to golf course lakes. Fish taken from these ponds had Hg levels too high for human consumption (161).

Grass roots can accumulate high levels of Hg whereas grass blades

TABLE 17

Composition of runoff water from detention ponds on a 106-Ha (263-A) golf course (after 101)

	Average Concentration	Average Yearly Load	
	mg/l-ppm	lb/A	kg/Ha
BOD:	11	12	13
COD:	53	59	66
Total Solids:	592	659	738
Organic N:		1.1	1.2
Soluble ortho-phosphate:		1.1	1.2

contain relatively low concentrations. Plant uptake of Hg is enhanced when As is present in the soil. When inorganic arsenicals and mercurials are applied together, grass clippings should not be removed. Clippings should not be allowed to enter lakes, streams, or creeks. Heavy metal residues remain in soils for several years, grass clippings also show their presence for a similar time period (161).

Only minor amounts of arsenicals and mercurials are used in the Basin (69). However, golf courses are major consumers and due caution should be exercised in their use. Chlorinated hydrocarbons, organophosphates, carbamates and other organic compounds are also used as pesticides on golf courses.

Since Hg accumulates in each step of the aquatic food chain, predatory fish often contain Hg levels of 10^4-10^5 times higher than that of the water they live in (160,265). Manifold enrichment occurred in fish in ponds next to golf courses, as indicated by Hg levels in the flesh of mature largemouth bass. Bass taken from golf course lakes contained 1-7 μg Hg/g wet tissue (1-7 ppm) (160,161). Background Hg levels in control bass were 0.1 μg/g (0.1 ppm).

Analysis of pond water samples shows that water is an insensitive indicator of Hg pollution. Data on sediments and aquatic vegetation suggest higher levels in golf course lakes (160,161). Many lakes with no known source of Hg pollution produce mature bass which contain significantly more Hg (0.1-1 μg/g, ppm) than the 0.5 μg/g, ppm, allowed by the U.S. FDA as the maximum for human food (161). Hazards to water quality emanating from golf courses can be avoided by good greens management and reuse of water through irrigation. National associations can play a major role in creating an awareness in green managers of the problems and can help in providing solutions.

3.4.11 Horseback Riding

Horseback riding in the Basin accounts for approximately 1.3% of the total annual requirements in recreation days for all activities.

The total annual recreation day requirement is expected to increase by a factor of 2.7 from 8.3 million in 1970 to 22.2 million in 2020 (124) (See Table 20).

The U.S. horse population has increased significantly in recent years. It was estimated that there were 3 million riding horses in the U.S. in 1960 (82) and the same number in 1965 (259). Recently, the USDA placed the horse population at 6.5 million, but riding clubs estimate the number at 10.5 million, or one horse for every 20 people (82). This suggests a figure of 1.5 million for the number of horses in the Basin.

Trail riding is the fastest-growing riding activity among the young: 40% of riding-horse owners are under 20 years of age (82). The great increase in the use of horses for recreational purposes may pose a potential water quality problem. The heavy weight of horse and rider may cause erosion of steep slopes or unstable soils, but values are unknown. Horses also produce relatively large amounts of solid and liquid excreta. Stable waste disposal methods or droppings on trails could affect water quality (Table 18). Typically, solid and liquid waste produced by a horse amounts to 6.6-7.3 metric T/y (7.3-8 T/yr) (55,259) or 19.9 kg (43.8 lb) /day (55). The total waste derived from horses in the Basin is therefore about 10.9 million metric T/yr (12 million T/yr). This amount of waste should be included in plans for disposal of other domesticated animal wastes in order to avoid deterioration of groundwater or surface waters by seepage and runoff.

At present there is no uniformity amoung states concerning registration of riding horses. Some members and officers of national horse organizations would like to see compulsory registration as an aid to tracing origins of outbreaks and preventing spread of disease, and as a means of tracing stolen animals . The number of riding horses being stolen and sold for slaughter is increasing. Standard registration would also provide statistics on the density and distribution of horses and assist in pinpointing areas where measures for control of wastes may be needed. The National organizations could be helpful in promulgating information on efficient methods of waste handling, and environmentally sound trail construction.

TABLE 18

Animal population and waste production in the United States (after 259)

Livestock	1965 Population, millions	Annual Waste Production, million tons*	
		Solid Waste	Liquid Waste
Cattle	107	1004	390
Horses	3	17.5	4.4
Hogs	53	57.3	33.9
Sheep	26	11.8	7.1
Chickens	375	27.4	-
Turkeys	104	19.0	-
Ducks (domesticated)	11	1.6	-

* Conversion factor:
1 ton = 0.91 metric ton

3.4.12 Snow Skiing

Skiing is an increasingly popular winter sport in the Great Lakes Basin. The 1974 recreation day requirement is estimated at 2.34 million days (124).

The typical skier in the Great Lakes Region is young (55% under 23 years of age), belongs to a higher-than-average income family, and has skied for a relatively short period of time (78% for 8 years or less); 80% of all skiing trips are for a weekend or less (64). Downhill, crosscountry and "hot-dog" (acrobatic or trick) skiing are various types of skiing practiced and to a limited extent ski jumping. Downhill skiing and "hot-dogging" require fairly steep grades, whereas cross-country skiers prefer lesser grades and thus use a wide variety of landscapes. The Great Lakes Basin has approximately 136 ski areas suitable for downhill skiing (63-66). Ski areas (see Fig. 5) are located in portions of the Basin that receive sufficient snowfall and have suitable topography. The Lake Superior Basin has 19 (66), the Michigan Basin 64 (64), the Lake Ontario Basin 17 (65), the Lake Huron Basin 22 (63), and the Lake Erie Basin 14 ski areas.

Cross-country skiing is becoming more and more popular throughout the Basin. National sales figures for cross-country skis show annual increases of approximately 75% per year (35). The low cost of cross-country skiing and the variety of land suitable for the sport are incentives for broad participation. All the state parks in Michigan now remain open for winter camping because of the surge in popularity of the activity, reflected in national club enrollments of over 100,000. However the rewards of cross-country skiing are more aesthetic than thrilling and the physical demands of the sport limit its popularity.

Recreation day requirements for skiing are expected to increase by 59% from the years 1970 (2.3 million) to 2020 (3.9 million)(124). The area needed for skiing is also expected to increase by 59% during this same time period (124). These figures do not reflect the recent increase in cross-country skiing. The impact of newer developments such as snurfing, skibobbing on "sitzskier" or snowmobile-powered

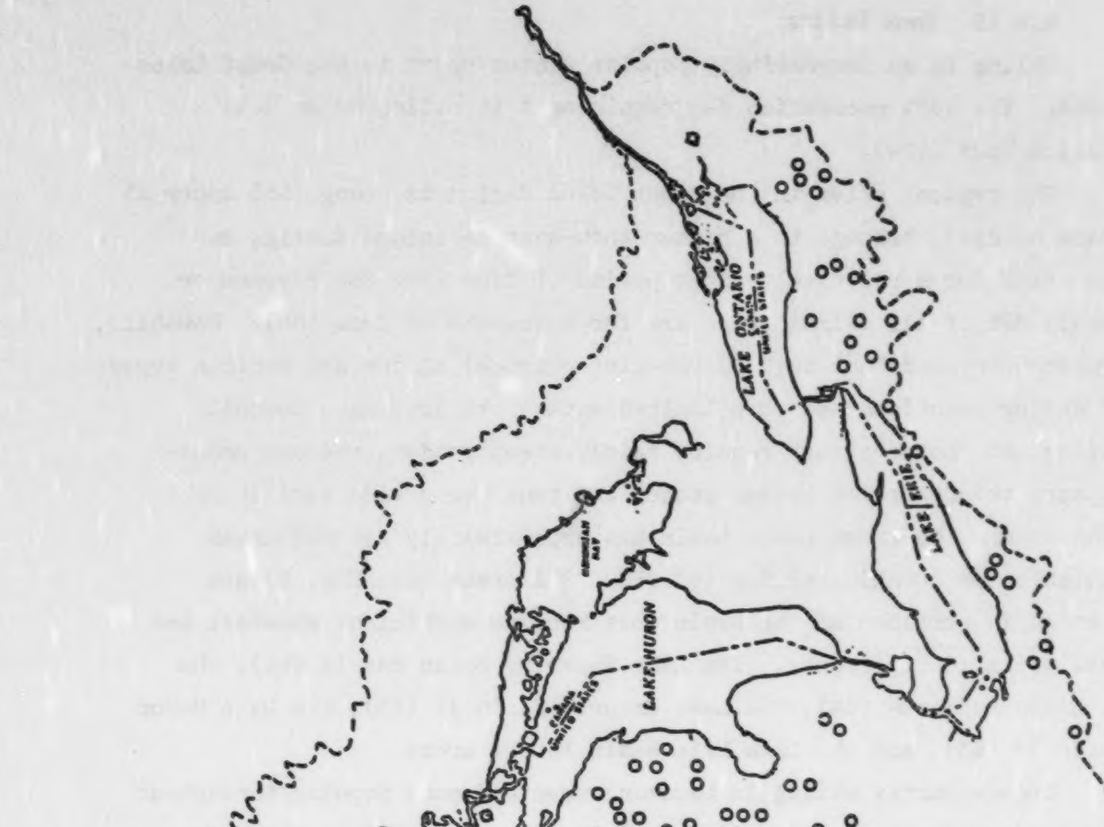

Figure 5. Location of ski areas in the Great Lakes Basin

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skijoring cannot be ascertained at present.

Some difficulties arise from overlap with other winter activities whose participants want to use the same areas as skiers. Conflicting activities include snowmobiling, hunting, hiking, snowshoe trekking, sledding and tobogganing (195). Provisions should be made to designate certain areas for each activity to promote safety and orderly development. These questions will affect demand for winter recreational land areas.

Information on water pollution resulting from skiing is somewhat limited. Erosion has been identified as one of the major potential problems in ski areas, and is considered more acute during the development and construction stages than during use of the slopes. Because of steeper topography, erosion is more prevalent in mountainous areas in the Western U.S. The National Environmental Policy Act restricts private developments on federal lands to 32.4 Ha (80 A), an insufficient area for ski developments. The acreage limitation unfortunately has restricted such development on public lands, where adequate provision to avoid erosion is prescribed. When intensive land developments are carried out on national forest lands, there is a requirement that the cleared land be seeded to provide vegetative cover as an anti-erosion measure. Seeding provides an effective control to avoid erosion, at minor cost.

Another major problem is management of wastes from resorts. Difficulties are encountered with both solid wastes and liquid or sewage wastes. Sewage wastes from ski areas can create a special problem in winter. Because 80% of all skiing is done on weekends, the abrupt influx in recreationists results in shock loads of sewage from ski areas to waste treatment facilities. Coliform counts can be 100 times the normal at weekends in waters in these areas (73). Because of overloading, sewage can pass through disposal systems without sufficient treatment. This problem can be aggravated by the effect of low temperatures which may reduce the efficiency of the biological process in systems that are not properly designed. The success of adequately designed septic systems even in the permafrost regions of Alaska (141) suggests that discharge from hot showers and flush toilets in the ski lodges could suffice to keep the temperature high enough in suitable systems for biological decomposition to continue unimpared even in extreme cold. Aeration systems have recently been tested as a means of more efficient biological treatment of ski area wastes (74).

Relationships have been determined for estimating the BOD$_5$ strength and solid contents of wastewaters from winter sports areas (73):

$$\text{BOD}_5\ (\text{lb/day}) = 0.17\ (E) + 0.0135\ (TV) + 0.173\ (G)^*$$

$$\text{SS}(\text{lb/day})\quad 0.059\ (E) + 0.013\ (TV) + 0.29\ (G)$$

where (E) is total number of full-time employees, (TV) is total number of visitors, (G) is number of overnight guests, (SS) is suspended solids. Peak flow rates of sewage discharge were 10 times the average daily flows.

Relationships for estimating water use at various lodges in winter sports areas were also determined (73). For day lodges:

$$\text{Water use (gal/day)} = 1.73\ (E)\ (Fu) + A\ (TV)^{**}$$

where Fu = the number of fixture units and A is a factor equal to 3.07 for lodges with 7-day-a-week operation and 1.08 for lodges with major use on weekends only.

The total water use at overnight lodges was found to be:

$$\text{Water use (gal/day)} = 1.73\ (E)\ (Fu) + B\ (G)^{**}$$

where the factor B is 22 for dormitory-type lodges with kitchen and bathroom facilities and 72 for dormitory-type lodges with attached restaurant and lounge. A summary of correlation analysis for waste production at skiing resorts is given in Table 19.

Great concern has arisen in some ski areas--such as Vermont--with the degradation of water quality in pristine mountain streams by wastewaters from ski resorts. Because of the extremely high purity of some of these streams, any introduction of treated wastewater effluent would bring about a prohibited deterioration in water quality, and consequently no discharge is permitted. Experimental methods of land disposal are currently being attempted to avoid stream disposal. Alternatively, wastes are being stored in holding facilities and used in warmer months

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* 1 lb/day = 0.454 kg/day
** 1 gal/day = 3.8 l/day

TABLE 19

Summary of correlation analyses for wastes produced at ski resorts (Data from 73)

Parameter, lb/day	Base Value Constant lb/employee/ day *	Average lb/total visitor per day	95% Confidence Limits lb/total visitors/day	Average lb/overnight guest/day	95% Confidence Limits lb/overnight guest/day
Suspended solids, SS	0.059	0.00031	± 0.01265	0.292	± 0.21
Chemical oxygen demand, COD	0.24	0.0168	± 0.0133	0.0844	± 0.23
Biochemical oxygen demand, BOD_5	0.17	0.0057	± 0.0078	0.041	± 0.132
Total Kjeldahl nitrogen, TKN	0.0473	0.0062	± 0.0105	0.0697	± 0.190
Total phosphates TPO_4	0.00098	0.00016	± 0.0007	0.0154	± 0.0116

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* = These values based on a total of 109 full-time employees contributing to base use at the areas studied.

$SS = 0.059\ E + 0.00031 \pm 0.01265\ (TV) + 0.292 \pm 0.21\ (G)$

$COD = 0.24\ E + 0.0168 \pm 0.0133\ (TV) + 0.0844 \pm 0.23\ (G)$

$BOD_5 = 0.17\ E + 0.0057 \pm 0.0078\ (TV) + 0.041 \pm 0.132\ (G)$

$TKN = -0.0473\ E + 0.0062 \pm 0.0105\ (TV) + 0.0697 \pm 0.190\ (G)$

$TPO_4 = 0.00098\ E + 0.0154 \pm 0.0116\ (G) - 0.00016 \pm 0.0007\ (TV)$

G = overnight guests
TV = total visitors
E = total number of employees

Conversion factors: 1 lb = 0.45 kg

as fertilizer on golf courses. However, evidence is increasing that mountain streams are hardly as pure as commonly believed, and not all coliform organisms found there originate from ski lodge sewage systems. Fecal coliform organisms are widespread in nature and there is little doubt that animal droppings from the wildlife populations are the main sources in some remote areas. The occurrence of total coliforms, fecal coliforms and fecal streptococi are highly variable depending upon season (temperature) and site, but total coliforms normally lie in the range of 150-300 per 100 ml. Under high stream flow conditions, caused by snowmelt and rainstorms, high counts of all species of coliform bacteria are found (163).

In areas allowing recreational use of protected watersheds, no correlation was found between coliform densities and human use level (169,236). However, in general, watersheds untouched by man can produce waters with substantial (>250/ml) coliform counts because of "natural" phenomena (117,236). Serological studies have identified wildlife as the source of the organisms (45).

Leachates from solid wastes generated in remote areas can pollute surface waters if disposal sites are at improper locations. Wastes, primarily from rooms and kitchens of overnight lodges, are generated at an average rate of 0.85 kg (1.87 lb)/visitor/day (234). Typical waste composition by weight is 34% food wastes, 33% other combustible wastes (paper, etc.) and 33% noncombustible wastes (bottles, cans, etc.).

Solid wastes from all facilities in day lodges average 1.33 kg (2.92 lb)/visitor/day. Waste composition by weight is 17% food wastes, 59% other combustible wastes and 24% noncombustible wastes (234). Methods recommended for solid waste disposal should be in accordance with the guidelines described in the Bureau of Solid Waste Management publication, "Sanitary Landfill Facts" (233).

With proper development and management, little or no contamination of water above "natural" levels should occur as a consequence of skiing.

3.5 Mobility of Pollutants in Soil-Water, Groundwater and Surface Water Systems

Contaminants and pollutants produced on recreational land or created by recreational activities can enter waterways by a variety of direct and indirect routes. Most of these have been discussed or alluded to in previous sections. As with the allied aspects of pollution load and pollution hazard, the main mechanisms are often specifically related to each particular land use or recreational practice.

Contamination of groundwater by leaching of nutrients, expecially NO_3 and PO_4 has aroused most concern (22,34,51,54,90,95,98,127,158,176, 177,188,204,208,211,240,257). Such losses occur mainly from septic tank effluent disposal fields associated with recreational homes or resorts in non-sewered areas (cf. Section 3.4.7); from heavily fertilized, heavily irrigated playing fields, golf courses and greens (cf. Section 3.4.10); from seepage of house manure piles (55); and from unsanitary dumping of putrescible solid wastes in heavily used but remote recreational areas (73,233,234,271).

Nutrient transport by runoff also can occur from all of the above sources especially if the facilities are constructed on unsuitable sites which are inadequately managed or maintained (100,161). Additional inputs arise from periodic flooding of recreational lands--parks, campsites,etc.--located in the floodplains of rivers draining into the Great Lakes. From environmental and economic considerations, recreational use of floodplain lands generally represent the safest method of utilizing these areas. Furthermore, management measures can be taken to minimize inputs even from recreational developments. Increased levels of sediment in runoff can result from soil erosion accelerated by some recreational activities (121,214), such as snowmobile and off-road vehicle use (104, 170,198,206,254,268,269), ski area development, heavy use of lakeside campsites (210),building and parking lot construction in recreational areas (214) and heavy traffic on riding and hiking trails (226). Direct inputs of contaminants can arise from fish hatcheries (70,94,145), as exhaust from marine engines (93,96,97,103,147,151,152,159,173,194,205, 223), sewage from boats (88,102,148,181,225), exhausts from vehicles or snowmobiles driven on frozen lakes (205), body bacteria and secretions from swimmers and waterskiers (129,154,218), wildfowl droppings (100, 110,157), lead pellets from wildfowl hunters (41,174,190,231,241,242), copper from lake treatments to eliminate swimmer's itch or nuisance algae (172,200), soil from shorebank erosion caused by waves from powerboats (217), or littoral use by recreationists (167,171) and litter from almost any activity. More detailed aspects of these pollutant inputs have been presented under the discussion of the pertinent activities in Section 3.4 above.

Some mobility of pollutants within lakes can occur even after they have become lodged in the sediments (78). This may result from natural turnover processes (54,157) or currents (78,200) within the lake. This intralacustrine redistribution can be accelerated by recreational activities, when bottom sediments are disturbed by bathing (cf. 154), boating, or marina dredging.

Unfortunately, the mechanisms by which recreational wastes reach lake waters rarely offer means of controlling inputs. Management measures designed to control the source are usually more effective. For instance, one good method of averting nutrient losses by leaching from recreational lakeshore properties is to perform soil tests to establish soil nutrient requirements before fertilizers are added to lawns (95). Because of the proximity of such properties to the lakes, excess fertilizer rapidly drains into the water (95). Similarly, since seepage from septic systems close to lakes can contribute up to ten times more nutrients than systems farther away (cf. Table 6), private sewage treatment systems should be kept as far away from lakes as practically possible.

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3.6 Natural Renovation Mechanisms Available to Remove Pollutants and Contaminants

3.6.1 Introduction

There are only a few natural mechanisms which serve to remove recreation-derived pollutants or contaminants from affected waters. However, inputs of pollutants and contaminants to water from recreational sources can be curtailed by a number of natural mechanisms, if management or technological measures are implemented to allow the natural processes to come into play.

3.6.2 Physical Mechanisms

Many physical measures can be adopted to prevent soil loss and achieve sediment control. Stabilization of lakeshores, footpaths, trails and roadways; contouring of recreational areas; and control of flow rates in runoff channels and stormsewers are important management techniques now being applied widely on recreational lands, public parks, campsites, etc.

The adsorption processes of soil are exploited to remove organic wastes, bacteria and nutrient elements from septic tank effluent emanating from unsewered recreational homes, resort buildings and campground facilities (cf. Section 3.4.7), and sewage effluent (240). Adsorption of wastes on peat is practiced with latrines in wilderness campsite areas (210).

Natural adsorption of toxic elements in the humic fractions of lake sediments, plays an important role in immobilization (cf. 200). Cu, As, Hg used in pesticides are immobilized in this way. Biological conversion of adsorbed mercurials to methylmercury in anaerobic sediments unfortunately offsets the benefits of this process. Other natural mechanisms, presumably sterilization by sunlight, also appear to play a role in destroying microorganisms in water. This is an important function because of its relevance to persistence and proliferation of pathogens in water. The pH and temperature of the water may also be important in determining the viability of pathogens from warm-blooded animals (112). On the other hand, adsorption of bacteria in sediments can extend survival of pathogens (112).

3.6.3 Chemical Mechanisms

Soluble phosphates in septic tank effluents can be trapped by percolating the effluents through soils containing lime or dolomitic limestone. Both inorganic and organic phosphates are precipitated as insoluble calcium salts.

Precipitation of soluble phosphate in recreational lake waters by flocculation with aluminum sulfate can be used to reduce the available P (264).

3.6.4 Biological Mechanisms

Biological reactions provide the main mechanisms for destruction or curtailment of recreation-derived pollutants. Some biological processes proceed naturally in lake waters, some of them interface with physical processes, especially in waste management procedures.

Heterotrophic organisms decompose a large proportion of organic wastes that enter lake waters. However, even under natural conditions, the rate of carbon input generally exceeds the rate of decomposition, so that accumulations of sediment and undecomposed detritus on lake bottoms can lead to shallowing of the water and transformation of the lake into marshland over geological periods of time. Of concern here are the accelerated inputs that occur as a result of recreational activites. As long as input is small, such as hydrocarbons from exhaust of normal boating densities, natural biological action is apparently capable of dealing with the load. However, it is not yet established whether similar wastes deposited during the winter, e.g. from snowmobiles on frozen lakes, can be efficiently decomposed, because biological activity is stopped by the low temperatures (cf. Section 3.4.3). Heavier recreational waste loads, e.g. of boat or raw sewage, cannot be adequately decomposed even during periods of high biological activity. Even under best seasonal conditions dilution effects, anaerobic conditions on lake bottoms and cold water temperatures slow decomposition rates.

Treatment of wastes is therefore best conducted on land. Provisions for septic tank systems for recreational homes and complexes, and onshore pumpout and treatment facilities for boat sewage allows biological waste treatment systems to protect waters from accelerated eutrophication.

Denitrification by facultative anaerobic bacteria in lake sediments or hypolimnetic waters can remove up to 11-15% of the annual nitrogen inputs into lake waters (54,158). Under ice cover, rates of denitrification can be many times the rate of assimilatory nitrate reduction (54).

Higher plants also play a role in retarding water quality impairment by recreation, when vegetative cover is used to forestall erosion on ski slopes, campsites, or trails used for skiing, sledding, snowmobiling, riding, bicycling, etc. Recent investigations (83) indicate that algae are capable of destroying undesirable bacterial species in infected waters. This represents an indirect benefit of eutrophication.

3.6.5 Remedial Measures

Despite the best natural, managerial and technological efforts to forestall lake eutrophication, gradual enrichment of lake waters with nitrogen, phosphorus and carbon is occuring (125). The eutrophic condition of many lakes makes portions of them unsuitable for recreational use. Among other considerations, the recreational need that these lakes could fulfill, reducing the pressure on other lakes has prompted researchers to consider potential mechanisms for lake rehabilitation (91,125,136,137). The techniques employed rely on curbing of nutrient inputs coupled with methods of increasing nutrient outflow or preventing nutrient recycling. One of the most popular approaches, because of its immediate cosmetic effect, involves harvesting of aquatic plants. Just as soil fertility is reduced by repeated harvesting of crops without fertilizing, the eutrophication of lakes can be retarded by harvesting of algae and cutting and removal of rooted macrophytes. The nitrogen and phosphorus contained in the plant tissues represents removal of a fraction of these nutrients from the recycling processes and nutrient pools in the lakes. The amounts of N and P in the plant tissues are rather low, and unless inputs are controlled, the efficacy of harvesting remains short-term.

Additional physical and chemical treatments have recently been attempted on an experimental basis (91); including dredging of nutrient-laden sediments, drawdown of lakes and flushing with low-nutrient water, phosphorus precipitation with alum (264), destratification (277), and artificial aeration of lakes and rivers used to circulate and add oxygen to the water (20,99,273,277).

While it is too early to assess the value of these procedures, it appears that nutrient input limitation is the single most desirable practice from the standpoint of long range management.

Some of the lake renewal mechanisms such as drawdown and flushing may simply transfer problem nutrients from one lake to another. Others, such as chemical treatments, leave nutrients in the lake, hopefully in a less accessible form. If the Basin is considered as a whole, only biological harvesting or dredging, coupled with land disposal, reverse the process of nutrient inflow. Since plant harvesting has the most immediate visible effects and other than cost is probably free from undesirable side effects, it is likely to become the most widely practiced lake improvement technique.

3.7 Probable Changes in Land Use Activities in Time (1976,1980,2020)

Substantial changes in land and water use will be necessary if present and future recreation needs for the Basin are to be met. Recreation day requirements within the total Basin for the years 1970,1980,2000, and 2020 are given for various activities, ranked by popularity in Table 20. A breakdown of the total recreational day requirements for the years 1970, 1976, 1980, and 2020 for the individual basins in the Great Lakes Basin

TABLE 20

Total recreation day requirements by activity in the Great Lakes Basin* (Data from 124)

	(In millions of days)				
	1970	1976	1980	2000	2020
Outdoor games/sports/golf	139.3	178.9	205.3	346.9	516.6
Driving for pleasure	99.3	115.4	126.1	169.2	223.7
Swimming	100.5	128.5	147.1	231	331.5
Walking for pleasure	75.5	86.3	93.5	132.5	185.9
Bicycling	60.7	67.9	72.7	98.7	134.7
Sightseeing	44.6	54.0	60.2	90.3	132.7
Picnicking	38.8	50.7	48.9	67.0	91.6
Power boating	21.9	28.2	32.4	51.1	77.2
Attending outdoor sports events	29.0	34.3	37.9	53.4	74.8
Fishing**	29.0	36.2	41.0	52.0	75.0
Snowmobiling**	27.0	34.8	40.0	50.5	72.0
Ice skating	9.3	12.5	14.6	24.0	37.2
Sledding and tobogganing	11.2	13.0	14.2	22.8	35.7
Hunting**	8.0	11.3	13.5	21.0	34.2
Camping	8.2	11.1	13.0	21.2	33.5
Horseback riding	8.3	9.6	10.5	15.2	22.2
Nature walks	9.4	10.8	11.8	15.9	21.7
Water skiing	3.9	5.7	6.9	12.5	20.7
Hiking	3.9	5.3	6.2	9.7	14.3
Attending outdoor artistic events	4.0	5.0	5.7	9.0	13.2
Canoeing	1.4	1.9	2.2	3.4	5.2
Sailing	1.3	1.7	1.9	3.0	4.9
Snow skiing	2.3	2.36	2.4	3.1	3.9
Off-road recreation vehicles**	2.0	2.3	2.5	3.1	3.8
Rock climbing**	0.2	0.26	0.3	0.4	0.5

*Recreation day = one person participating in outdoor recreation for all or most of one day.

**Recreation day requirements were estimated by P.I.

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system is presented in Table 21. The approximate needs in acres and hectares for Class I (high density recreation) and Class II (general outdoor recreation) lands and for recreational waters are given in Table 22.

Land to satisfy the needs for exclusive recreational use will have to come from other recreational land classes or from agricultural land. It is reasonable to assume that land for recreational expansion will be derived from agricultural land in areas close to metropolitan centers. To make up these losses forest lands may be converted to fulfill the expanding needs of agriculture. To either supply Class I and Class II needs, or to replace lost agricultural lands, some land may be taken from the present Class III, IV and V recreational lands (natural environment, outstanding natural and primitive areas).

The additional areas of recreational water needed will have to be derived from the Great Lakes, inland lakes and rivers. The future development of reservoirs is expected to add little to the supply of recreational water resources. Moreover, although the bulk of the vast surface of the Great Lakes is currently unused for recreation, this cannot be considered as a latent resource available to supply the future need. The usefulness of the Great Lakes is restricted for most water-based activities to sheltered bays or areas within about 304.8 m (1000 ft) of the shore. The fulfillment of future needs will therefore have to rely heavily on increased development of inland lakes or renovation of inland lakes or river areas that have become unsuitable for use through eutrophication or pollution.

3.8 Projected Seriousness of Future Pollution Problems Associated with Recreation and Recreational Land and Water Use

In view of the inadequacies of and discrepancies in some of the information available on many quantitative aspects of recreation participation, and on the magnitude of the impact that recreational activities and recreational land and water uses have on water quality, it is difficult to reliably assess the detrimental impact that recreation has at

TABLE 21

Total recreation day requirements by lake basin in the Great Lakes System, in thousands*

Lake Basin	1970	1976	1980	2000	2020
Lake Superior	14,554	17,077	18,759	25,586	34,347
Lake Michigan	298,237	361,136	403,070	608,126	874,384
Lake Huron	38,897	47,459	53,167	81,059	116,034
Lake Erie	217,982	264,847	296,091	449,414	648,834
Lake Ontario	67,497	81,195	90,329	133,888	190,188
Total for most activities in the Great Lakes Basin (124)**	637,167	771,714	861,416	1,298,073	1,863,787
Total for all activities in the Great Lakes Basin***	703,367	856,574	958,716	1,425,073	2,049,287

*Recreation day = One person participating in outdoor recreation for all or most of one day.

**These figures do not include the totals for the activities of fishing, snowmobiling, hunting, off-road recreation vehicles, or rock climbing.

***These figures include the totals for those activities not included in (124), namely, fishing, snowmobiling, hunting, off-road recreation vehicles, and rock climbing.

TABLE 22

Approximate needs for recreation land and water (Data from 124)

Lake Basin	Year	Land		Water
		Class I	Class II	
Lake Superior	1970	1,052 Ha, 2,600 A	728 Ha, 1,800 A	-
	1976	1,611 Ha, 3,980 A	1,068 Ha, 2,640 A	-
	1980	1,983 Ha, 4,900 A	1,295 Ha, 3,200 A	-
	2020	5,504 Ha, 13,600 A	3,642 Ha, 9,000 A	-
Lake Michigan	1970	17,401 Ha, 43,000 A	30,271 Ha, 74,800 A	48,159 Ha, 119,000 A
	1976	26,435 Ha, 65,320 A	44,719 Ha, 110,500 A	102,064 Ha, 252,200 A
	1980	32,456 Ha, 80,200 A	54,350 Ha, 134,300 A	138,000 Ha, 341,000 A
	2020	117,402 Ha, 290,100 A	180,089 Ha, 445,000 A	635,775 Ha, 1,571,000 A
Lake Huron	1970	3,602 Ha, 8,900 A	5,544 Ha, 13,700 A	-
	1976	4,913 Ha, 12,140 A	7,001 Ha, 17,300 A	-
	1980	5,787 Ha, 14,300 A	7,972 Ha, 19,700 A	-
	2020	16,026 Ha, 39,600 A	24,282 Ha, 60,000 A	28,329 Ha, 70,000 A
Lake Erie	1970	8,984 Ha, 22,200 A	19,304 Ha, 47,700 A	9,308 Ha, 23,000 A
	1976	14,302 Ha, 35,340 A	29,114 Ha, 71,940 A	47,673 Ha, 117,800 A
	1980	17,847 Ha, 44,100 A	35,654 Ha, 88,100 A	73,250 Ha, 181,000 A
	2020	67,827 Ha, 167,600 A	131,202 Ha, 324,200 A	456,900 Ha, 1,129,000 A
Lake Ontario	1970	4,047 Ha, 10,000 A	7,851 Ha, 19,400 A	-
	1976	6,014 Ha, 14,860 A	10,279 Ha, 25,400 A	-
	1980	7,325 Ha, 18,100 A	11,898 Ha, 29,400 A	7,284 Ha, 18,000 A
	2020	22,582 Ha, 55,800 A	38,932 Ha, 96,200 A	61,109 Ha, 151,000 A
Total Lake Basins	1970	98,786 Ha, 244,100 A		57,467 Ha, 142,000 A
	1976	145,649 Ha, 359,900 A		154,108 Ha, 380,800 A
	1980	176,892 Ha, 437,100 A		218,535 Ha, 540,000 A
	2020	607,487 Ha, 1,501,100 A		1,182,112 Ha, 2,921,000 A

present on the water resources in the Great Lakes Basin. It is correspondingly more difficult to predict with any great accuracy and assurance what the future overall effects of recreation on water quality will be. Any such projections are of necessity highly speculative, especially in view of the fact that novel technological developments may produce new recreational pursuits of unknown environmental impact that can grow to gigantic proportions within a few years, (e.g. as has been the case with snowmobiling) or that unknown factors such as gasoline shortages may radically alter present participation predictions.

However, on the basis of information available at present for certain recreational activities, (some of which have been in wide practice for over forty years) a few trends can be recognized, and more reliable predictions can be made for these specific areas. The information on several activities is quite detailed, mainly because these were the activities most strongly suspected of influencing water quality. In general, it has been found for each of these activities that with good management practice and improved technology, serious pollution problems can be avoided. By analogy, therefore, it is to be expected that the other aspects of recreation, which have not been scrutinized so closely, will be of lesser impact or more amenable to control through management procedures or technological improvements.

An assessment of the importance of the roles that various types of recreational land and recreational activities are expected to play in influencing the quality of waters in the Great Lakes drainage basin is presented in Tables 1 and 2. These forecasts allow for expected increases in recreational participation, and show the minor overall influence of recreation-related pollution problems and the reductions in input loads that are expected to be produced per unit area for recreation participants through application of improved control methods. In no case can any hazard be considered extreme; at most, acute problems will arise only transiently in localized, overused areas. Moreover, even the relatively mild overall impact of recreation is expected to be mitigated as better management practices, newer legislation and improved technologies begin to take effect.

The one area which appears to be most serious at present, namely that of nutrient influx to surface waters from unsewered recreational homes and resorts, is expected to diminish gradually, since major efforts have been and are being exerted to improve the performance of private domestic waste treatment systems. Regardless of any advances in technology in this field, the present situation can be improved and future increases in adverse impacts can be forestalled by application of what is already known. This will, however, require some departure from previous practices, and consequently will necessitate an educational program to insure acceptance. The key to avoiding water problems with septic tank/soil disposal systems is to keep them far enough away from lakes or streams that they might pollute. This implies that the dwellings or developments being serviced by the system must also be far enough away from the water, a circumstance which many recreationists may be unwilling to accept unless they realize the adverse effect that their proximity will have on the quality of the water they want to use for recreation. In all areas, greater awareness and increased environmental concerns of recreationists, the supply industries and controlling agencies are likely to lead to diminution of pollutant loads from recreational undertakings.

3.9 Review of Institutional Arrangements to Regulate Land Use and Control Pollution

3.9.1 Nature of Existing Legislative, Regulatory and Enforcement Programs

3.9.1.1 Principal Federal Laws Providing for Recreational Needs

Initial legislative sanction was provided by the Organic Act of 1963 for the USDI Bureau of Outdoor Recreation to provide adequate outdoor recreation resources for the Nation for the present and the future (16 United States Code, §§ 460L-460L-3).

The BOR also executes most of the responsibilities delegated by law to the Secretary of the Interior under the Land and Water Conservation Fund Act of 1965 and a number of the Secretary's functions under the Federal Water Project Recreation Act (16 USC, §§ 460L-12).

The Land and Water Conservation Fund Act of 1965 created a land and water conservation fund to assist the states *inter alia* in development of recreational areas and to assist in Federal acquisition and development of recreational areas (16 USC, § 460L-4).

The Federal Water Project Recreation Act of 1965 (16 USC, § 460L-12) established uniform policies toward benefits and costs of recreation and enhancement of fish and wildlife for most federal water resources projects.

The Wild and Scenic Rivers Act of 1968 (16 USC, Supp. V, §§ 1271-1287) instituted a national wild and scenic rivers system to preserve selected rivers of the nation in a free-flowing condition; to protect these rivers and their immediate environments which possess outstanding scenic, recreational, geologic, fish and wildlife, historic, cultural and other similar values; to protect the water quality of these rivers; and to fulfill other vital national conservation purposes.

The law dictates that each component of the national wild and scenic rivers system be administered so as to protect and enhance the values which justified its inclusion in the system. The Federal Power Commission is prohibited from authorizing any construction or development which would have an adverse effect upon the selected wild rivers.

The National Trails System Act of 1965 (16 USC, § 1283) established a national system of recreation and scenic trails, primarily near urban areas, to satisfy the increasing outdoor recreation needs of the expanding population by promoting public access to, travel within and enjoyment and appreciation of the recreation areas of the Nation. Both wild and scenic rivers, and national scenic trails can be authorized and designated only by an act of Congress.

National forests may be established for the purpose of "securing favorable conditions of water flows" (16 USC, § 475). In the earliest law pertaining to recreation, the National Park Service Act created the National Park Service in the USDI to preserve national parks, monuments and reservations for the scenery and the natural and historic objects and wildlife (16 USC, § 1).

The Surplus Property Act of 1944 (50 USC app. § 1622, 1970) as amended, allows disposal of Government surplus property and land to any state or political subdivision to be used for a public park, public recreation area or historical monument.

The Multiple Use-Sustained Yield Act of 1960 declared the policy of Congress that the National Forests be utilized for outdoor recreation, timber, watershed and wildlife and fish purposes under the jurisdiction of the USDA Forest Service (16 USC, § 525). It also directs the Secretary of Agriculture to cooperate with the states and their political subdivisions to develop and use water resources (16 USC, § 1001).

The National Wilderness Preservation System Act authorizes that certain areas be designated by Congress as wilderness areas and remain unimpaired for future use and enjoyment as wildernesses (16 USC, § 1131).

In the framework of the Farmers Home Administration Act it is also the responsibility of the Secretary of Agriculture to develop land conservation and land utilization programs to control soil erosion, preserve natural resources, protect fish and wildlife and develop and protect recreation facilities (7 USC, §§ 1010-1011).

The U.S. Army Chief of Engineers is authorized to construct, maintain and operate public parks and recreational facilities at water resource development projects under the control of the Department of the Army and to delegate this authority to local interests (16 USC, § 460d).

The Water Resources Planning Act (42 USC, §§ 1962-1962d-3) directs optimum development and conservation of the Nation's natural resources through coordinated planning by federal, state, local and private bodies.

The Federal Water Pollution Control Act of 1948, as amended, provides for the development of a comprehensive water pollution control program in which due regard be given to the improvements which will conserve waters *inter alia* for recreational purposes (62 Stat. § 1155, as amended, including P. L. 92-500).

Definition of terms relating to most of these laws, and details concerning the provision and apportionment of funds for their implementation, cost-sharing with states, disposal of public lands, delegation of authorization for implementation and administrative responsibilities to states or local interests and other allied matters have been recently reviewed in an appendix to the GLBC Framework Study (123). Under terms of Public Law 88-29 of 1963, the Department of the Interior was directed to prepare and submit to Congress a Nationwide outdoor recreation plan. The second draft of this document has recently been compiled and a digest is available (59). The new report has been severely criticized for failure to adequately project future needs (3).

3.9.1.2 Other Federal Regulations Affecting Recreation

In addition to direct federal legislation and control of recreation, other federal institutional arrangements affect recreation when the latter interfaces with such matters as water quality, land use, etc. For instance, federal assistance can be provided for protection of recreational (and other publicly owned) beaches from erosion (33 USC, § 426e). Under the terms of the Fish and Wildlife Coordination Act (16 USC, § 661) the Secretary of the Interior may provide assistance to state, federal, public and private agencies and organizations to develop, protect and stock wildlife habitats and to restore and protect sport and recreational fishing (16 USC,§ 777). Similarly the Wetlands Loan Acts (16 USC,Sec.715k-3) authorized appropriations to help protect wetlands and waterfowl habitats.

The Rivers and Harbors Appropriation Act of 1899 makes it unlawful to discharge into navigable waters of the U.S. any refuse matter other than that flowing from streets and sewers in a liquid state (33 USC, § 407).

The Water Pollution Control Act of 1948 and its amendments protect water resources by setting up a national policy for the prevention, control and abatement of water pollution (33 USC, § 466a). Primary responsibility and rights of enforcement are delegated to the states (33 USC, § 466b). The Water Quality Improvement Act of 1970 (84 Stat. 91) specifically provides for regulation of pollution of navigable waters by oil, or discharge of sewage from vessels and authorizes federal-state cooperation for elimination or control of water pollution within Great Lakes watersheds. Effective federal standards for marina sanitation devices are to be developed and enforced (221). The EPA, as administrator of the Act, is authorized to provide shared funding for sewage and waste treatment installations and for demonstrations of new or improved waste treatment facilities or procedures. These aspects of the law affect such recreational parameters as unsewered homes, campgrounds or resorts and marine pleasure craft engine emissions and waste discharges. Tentative standards for marine sanitary devices have recently been issued (43).

The USDA Soil Conservation Service has broad authorization to study and to implement measures to prevent soil erosion from damaging natural resources (16 USC, § 590a *et seq.*). This responsibility impinges upon the area of erosion induced or accelerated by recreational use of forest lands, wilderness areas, and recreational lands, or by recreational activity on public, state or private lands.

The EPA now also establishes water quality criteria for aesthetic and recreational purposes encompassing pH, turbidity, color, taste, odor, floating debris, scum, etc. Fecal coliform bacteria are to be used as indicator organisms for possible contamination of surface waters by human pathogens. Some of these factors are affected by recreational water use, e.g., bathing, swimming, boating. At present, there are no standards for regulation of viruses for recreational waters (8).

Rules and regulations have been set up for submitting environmental impact statements concerning proposals for legislation and other major federal actions significantly affecting the quality of the human environment (109).

The Bureau of Outdoor Recreation Rules on Environmental Impact Statements requires mandatory preparation of statements whenever recreation and related resource studies may be used for individual grants-in-aid under the Land and Water Conservation Fund concerning matters which have significant environmental effects or when such studies are known to be likely causes of controversy (109).

In 1972, the National Academy of Sciences appraised water quality

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criteria for the EPA (19). Novel subjects such as the recreational impact of boating, disease vectors, nuisance organisms, aquatic vascular plants and viruses in relation to public water supplies were considered. Many recommendations were incorporated into the EPA prescriptions discussed above.

Since 1970 all federal agencies regulating any real property, facility or federal public works activity must insure compliance to water quality standards in their administration (Public Law 91-244, 84 Stat. 91).

The National Environmental Policy Act of 1969 (Public Law 91-190, 83 Stat. 852) and Executive Orders Numbers 11514 and 11507 of 1970 concerning air and water pollution apply fully to federal recreation projects. The Department of Transportation Act (49 USC, § 1651 *et seq.*) which established the Department of Transportation directs it to respect the natural beauty of the countryside and public park and recreation lands, wildlife and waterfowl refuges, and historic sites in implementing transportation policy.

Section 10 of the River and Harbor Act of March 3, 1899 (30 Stat. 1151; 33 USC, § 403) requires plans for wharves, piers, dolphins, booms, weirs, breakwaters, bulkheads, jetties, or other structures, and excavation or fill in navigable waters be recommended by the Chief of Engineers and approved by the Secretary of the Army. This affects the area of marina construction and maintenance.

3.9.1.3 State Water Laws Affecting Recreation

A summary of existing legislative, regulation and enforcement programs for the several states of the Great Lakes Region can be found in a Great Lakes Basin Framework Study Appendix (123).

Sections of interest in this report include summaries of constitutionality and water use legislation, the common law relating to water resources, informal governmental relations and water policy, a comparative analysis of the powers, programs and policies of the states, public institutional arrangements, and federal and state mechanisms of coordination for the Great Lakes.

All of the Great Lakes States have some kind of program for scenic preservation. In many instances the program is conducted in cooperation with the Federal Government. Illinois, Michigan, Minnesota, Ohio and Wisconsin have passed specific river or area preservation statutes. Indiana, Michigan, New York, Ohio, Pennsylvania and Wisconsin have programs for historic site preservation.

All states have ongoing programs for providing public access sites to inland and Great Lakes waters. Indiana, Michigan, Ohio and Pennsylvania have legislative power to zone water surface areas for specific recreational use.

Shoreland management of the Great Lakes in most states is defined by rules or statutes distinguishing public and private rights. Permits are normally required before private owners can engage in any construction, dredging, fill-in or similar operations which would alter the shoreline of the lake. Most states unfortunately do not have zoning laws to reduce or prevent shoreline erosion from construction or development. Most states delegate this authority to the local level.

All Great Lakes States have specific or inferred authority to protect against sediment and erosion damages; however, most states do not engage in streambank stabilization other than on state land or under general flood control practices. Michigan, Ohio, Pennsylvania and Wisconsin have standards for sediment pollution in their water quality standards.

Pollution control in the Great Lakes States is the responsibility of boards or commissions except in Pennsylvania where such responsibilities are handled by an executive department. State agencies have ultimate responsibility for controlling pollution in all waters of the state.

Illinois, Indiana, Michigan, Minnesota and Ohio have established water quality standards for both effluent and receiving waters. New York, Pennsylvania and Wisconsin have standards for streams (receiving waters) only.

To ascertain whether an activity is polluting state waters, essentially three procedures are employed among the various states. Illinois, Indiana, Minnesota, New York and Ohio require a public hearing before water quality standards are established for any waterway; these are then used to designate what is or is not unlawful pollution. Although not specified by law, the controlling boards of Michigan and Pennsylvania do conduct public hearings. In Wisconsin, hearings are held on a voluntary basis. An anti-degradation clause is included in the standards of Illinois, Indiana, Michigan, New York and Ohio to protect waters of higher quality than the established standards. Water quality must be raised to meet the standards in all of the Great Lakes States. Ohio and Illinois have provisions for exceptions.

The statutes of Illinois, Michigan, New York, Pennsylvania and Wisconsin make express provisions as to whom can invoke agency action from outside the agency. In all states (with the possible exception of Minnesota) the pollution control agency's staff monitors water quality and conducts investigations for agency action.

All Great Lakes States have explicit authority to enter and inspect the premises of suspected polluters. The states vary as to procedures for coping with identified or suspected polluters. The procedure usually involves an initial agency order for abatement, which can either be complied with or appealed through a hearing or the courts.

All states except Minnesota provide for fines for violations of pollution control laws. Illinois, Indiana, New York, Ohio and Pennsylvania laws also allow for imprisonment of convicted violators. Illinois and Michigan also allow the state to collect compensation for losses of fish and wildlife.

Illinois, Indiana, Michigan, Minnesota, Pennsylvania, New York and Wisconsin are expressly authorized to act against potential pollution. All states have indirect sanction methods through mechanisms such as permit issuance.

The Water Quality Act of 1965 set the deadline of June 30, 1967, for states to adopt water quality standards and a plan for implementing and enforcing these standards. Criteria acceptable to the Secretary of the Interior became the water quality standards applicable to the state, interstate and coastal waters.

Some of the water quality standards for recreational use of waters of the Great Lakes States are compared in Table 23. Most of these state standards are currently under revision, because the most recent EPA criteria for recreational water quality are more stringent than state standards. For safety reasons, as well as quality requirements, the EPA prescribes that clarity must be such that a Secchi disk is visible at a minimum depth of 1.2 m (4 ft). Fecal coliforms are to be counted as indicators of potential human pathogens and should not have an average greater than 2000/100 mls nor a maximum greater than 4000/100 mls for recreational waters where there is little possibility for ingestion. In waters used for primary contact, e.g. swimming, the log mean count should not exceed 200/100 mls and levels in no more than 10% of samples collected during any 30-day period should exceed 400/100 mls. Other standards require a pH of 6.5-8.3 and that temperature should not exceed 29.4°C (85°F) (8).

The discrepancies among standards set for total coliform or fecal coliform reflect the uncertainties among workers who try to correlate disease incidence with water quality. An EPA investigation into recreational water quality concludes that fecal coliform standards are correlated with total coliform incidence and not to salmonella or disease incidence, and recommended more quantitative studies on salmonella/fecal coliform ratios. According to available data and experience, existing standards (1000/100 ml total limit) for coliforms are unnecessarily strict (186). Continuation of research is expected to lead eventually to a good correlation between coliform analysis and health risk to recreationists.

All of the Great Lakes States with the possible exception of Pennsylvania, have passed regulations requiring "total retention" of all sewage during boat trips. This usually means that vessels must be equipped with a sealed holding tank, which can be pumped out only at approved facilities. There is some question as to the extent and efficacy

TABLE 23

State requirements for recreational water quality

State	Coliform Primary	Coliform Secondary	pH	Temperature
Illinois (26)	5000/100 ml			
Michigan (27)	10 consec. samples not >1000/100 ml or 20% >5000/100 ml	10 consec. samples not >5000/100 ml nor 20% >10,000/100 ml	6.5–8.8 w/max. induced variation of 0.5 unit within this range	32.2°C (90°F) maximum
New York (29)	All effluents must be effectively disinfected or 2400/100 ml	All effluents must be effectively disinfected	6.5–8.5	
Ohio (30)	Not >100/100 ml (geometric mean) nor 10% >2000/100 ml	Same as Primary		
Pennsylvania (31)	Not >5000/100 ml as monthly geometric mean	Same as Primary	7–9	Not > - 15°C (5°F) rise above natural or 30°C (86°F), whichever is less
Wisconsin (32)	Not >1000/100 ml and max. not >2500/100 ml	Not >5000/100 ml average w/ no more than 20% of samples >20,000/100 ml		
Minnesota (28)	Not >1000/100 ml	Not >5000/100 ml	6.5–9 6.0–9.5	30°C(86°F) 33.9°C (93°F)
Indiana (118)	Not >1000/100 ml			

of current procedures. Proposed federal regulations for on-board waste treatment devices have only recently been issued (43). The trend of both federal and state regulation is toward "total retention" by either holding tanks or on-board incinerators. By 1980 or sooner (depending on final specifications by the Coast Guard) all boats will probably have to be equipped with one of the two devices (cf. 4,37). Specifications for septic tank installations for non-sewered dwellings are issued by the Boards of Health of the various states and published in the State Administrative Codes. There is great divergence among the codes for the various states. However, the specifications are continually being updated and improved in accordance with availability of better units and design. Unfortunately, many systems have been in operation for decades which were constructed and installed under less stringent older guidelines.

Off-road vehicles continue to increase in number yearly. In Feb., 1972, the Upper Great Lakes Regional Commission initiated model legislation and related studies to help control the increasing use of trail bikes, fourwheel drive vehicles, snowmobiles and other ORRVs. A complete model legislative program is now available from the Commission (245). It covers registration, insurance, highway operation, violations, required equipment, local ordinances and general enforcement provisions, duties in event of accidents and reports of same, education and training programs, special events and suspension and revocation procedures.

Specific maximum noise levels on a decibel scale have been set for motor vehicles in California and New York. No specifications have been set forth in the Upper Great Lakes Regional Commission Model Legislation (245), or by most states.

Several public agencies have taken steps to avoid damage to vegetation and terrain by off-road vehicles. The USDA Forest Service designed snowmobile trails in eastern Great Lakes States to avoid areas of wildlife use and damage to soil and vegetation. The Bureau of Land Management has been concerned, but lacks regulations and funding for enforcement. Minnesota, Michigan and New York prohibit snowmobile operation in areas where such damage may occur. It has been recommended that the size and type of snowmobile and other ORRVs be considered when formulating regulations of their areas of use (37).

Most states have laws against hunting from a motor vehicle, but only a few states have legislation which protect animals from harassment by snowmobiles. Nonmotorized zoning for fish and wildlife protection and other ecological and recreational reasons has been proposed as an administrative and enforcement solution for public agencies (37).

Many states provide specific rights and privileges to ORRV users, but few states or federal agencies have specified rights for other recreational pursuits. New York, Vermont and Minnesota regulate snowmobile use in forest preserves to specific trails and prohibit cross-country travel. Michigan has started demonstration areas where data can be collected on environmental damage and user behavior and response to regulations. The National Park Service restricts snowmobiles and ORRVs to existing park roads. The Forest Service has encouraged snowmobile use in the past, but is recognizing that it must regulate use in some areas and zone certain areas out of bounds.

A program of registration and ORRV identification is important for ORRV operators safety, and for protection of landowners and other citizens from vandalism and theft. Registration with vehicle inspection would help insure vehicle safety and operator competence while a requirement for prominent display of an identification number would help counter vandalism, theft and trespass.

3.9.1.4 Recommendations for New Regulatory Programs

The Subcouncil on Leisure of the National Industrial Pollution Control* has recommended establishment of federal standard noise levels and limits for pleasure boats, motorcycles, snowmobiles, all-terrain vehicles and outdoor powered equipment. Noise levels at 50 feet should be reduced from a 1970 standard of 68 decibels to a 1983 standard of 62 db for rotary power motors and from a 1970 standard of 88 db to a 1983 standard of 70 db for snowmobiles (196).

The Subcouncil also urged that a pollution analysis procedure be

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* Disbanded 1973.

adopted by the recreational products industry to identify sources of pollution and to prescribe methods for abatement. The report also requested manufacturers of outdoor recreational equipment to continue efforts to minimize environmental effects of their products, and to develop codes of environmental ethics for recreation participants. The subcouncil also suggested an experimental program of limiting access to some public recreational areas to individuals passing specific tests on sound environmental practices (196).

There is also a need for a uniform traffic code for boats. This would have impacts both on boater safety and on environmental questions. For example, speed restrictions within a certain distance from shore would prevent wave erosion of banks and reduce interference of speedboat users and water skiers with swimmers and fishers. Time restrictions for certain uses would alleviate overuse of some lakes. For example water skiing could be restricted to a few daylight hours around noon. This would not interfere with prime fishing time and equalize the use between water skiers and anglers.

Specific regulations covering disposal of wastes should be drawn up for the growing recreation of ice fishing.

Lastly, a uniform policy should be set up concerning use of floodplain areas, encouraging their use as recreational areas, since this probably represents their least environmentally hazardous use. Sociologically, this should also be the most attractive use, since problems associated with flooding of dwelling basements, industrial complexes and the like are avoided.

Section 4

SUMMARY OF RELEVANT ONGOING RESEARCH, DEMONSTRATION AND MONITORING PROGRAMS

4.1 Preamble

The research, demonstration and monitoring programs currently underway which may provide basic information relative to the effects of recreational areas and activities on water quality are diversified. Ongoing projects have therefore been grouped into arbitrary categories depending on whether the studies relate to 1) the general impact of recreation on water quality, 2) the general impact of recreation on environmental quality, 3) specific impacts on water quality, or 4) specific recreational activities. For each study, the title, name and address of the principal investigator(s), the source of the funding, if known, and, where appropriate, the BOR recreational land class primarily concerned are indicated. This information is followed by a short statement outlining the nature and aims of the study and the type of pertinent information that may be forthcoming, if these are known.

4.1.1 Studies Concerning the Impact of Recreation on Water Quality

a)	Impact of Water Based Recreation	D. J. Allee Cornell University SUNY College of Agriculture School of Agriculture Ithaca, N.Y. 14850	BOR Land Class II

The study is seeking to relate the capacity of water and its associated land resources to provide recreational services (with the growing demand for those services) in the context of comprehensive water resources planning.

The objective of the study is to develop and test theoretically sound operational planning procedures while adding to knowledge of water-based recreation, its economics and technology.

b) Recreation Impact on Specific Wyoming Drainages	A. A. Beetle University of Wyoming Agricultural Exp. Station Laramie, Wyo 82071	BOR Land Class V

The impact of recreation on the watershed is being evaluated in terms of vegetation responses and water quality potentials for recreation, and ways are being sought to integrate recreation with other land uses, in order to preserve wilderness values.

c) The Origin, Effects and Control of Turbidity in an Urban Recreational Lake	S. M. Bemben University of Massachusetts School of Engineering Amherst, Mass. 01002	BOR Land Class I

The physical, chemical and biological actions which create turbidity in an urban lake are being studied by means of field and laboratory investigations.

d) Small Scale Liquid Waste Disposal	W. C. Boyle, J. Bouma et al. University of Wisconsin Colleges of Engineering, Agri. and Life Sciences Madison, WI 53706 (E.P.A. funding)	BOR Land Classes I and II

Studies are being conducted of the operation and causes of failure of septic systems. Measurements of losses of N, P, bacteria and viruses, and evaluations of alternative treatment methods are being made. Methods of preventing or remedying seepage bed failures are being sought.

e) Hydrologic Study of Prince William Forest Park	G. Allan Brown USDI Geological Survey Water Resources Division 200 W. Grace St. Richmond, Va 23220	BOR Land Class III

The water quality in streams is being examined. The streams are polluted primarily by domestic sewage before they enter the park.

f) Upper Great Lakes Region Recreational Planning Study	Rollin Cooper University of Wisconsin Recreational Resources Center 1815 University Ave Madison, WI 53706	BOR Land Class II

The overall aim of this study is to construct a computer model of the area in order to derive the accessibility of recreational areas in the Upper Great Lakes Region.

Traffic flow patterns are being examined on a county-by-county basis for a nine-state area. This information will assist in making more accurate predictions of recreational distribution and needs.

g)	Nutrient Runoff from Golf Courses	Richard Duble Texas A & M University College of Agriculture College Station, Tex 77843	BOR Land Class I

Leaching and runoff losses of plant nutrients from golf course fertilizer applications are being measured.

h)	A Eutrophication Model of the White River Basin above Beaver Reservoir in Northwest Arkansas	R. A. Gearheart University of Arkansas Water Resources Research Center Fayetteville, Ark 72701	BOR Land Class II

An evaluation is being made of various nutrient contributors to a reservoir. The purpose of the study is to predict by mathematical model the rate at which this relatively new reservoir will accumulate nutrients.

i)	Influence of Subsurface Waste Disposal Systems on Receiving Waters	K. D. Kerri Sacramento State College School of Engineering Sacramento, Calif 95819	BOR Land Classes I and II

The aim of this study is to develop prediction models capable of indicating the influence of existing and proposed subsurface waste disposal systems on receiving waters. This information is important in connection with pollutants entering water from unsewered homes.

j)	Recreational Use of Drinking Water Reservoirs	L. N. Kuzminski University of Massachusetts School of Engineering Amherst, Mass 81002	BOR Land Class I

The essential variables which may influence pollutant dispersion in a reservoir from a shoreline source typical of body-contact water recreational activity are being identified, in order to develop a model characterizing the processes of pollutant dispersion and decay.

Guidelines are being formulated to predict the location and fate of bacteria from human origin for a given level of body-contact water recreation. The objective is to determine which areas are amenable for bathing and, for a given area, the extent of treatment necessary to purify water at the drinking supply inlet.

This program was established with public agencies by which the model could be used as a decision-making aid.

k)	The Properties of Surface Films on Lakes and Reservoirs	P. A. Mangarella University of Massachusetts Water Resources Center Amherst, Mass. 01002	BOR Land Classes I and II

Surface film contamination from swimmers and outboard motors may be one important means by which recreational use affects water quality. Surface film phenomena are being investigated with the objective of developing criteria which will help guide public health authorities to evaluate surface film pollution risks.

l)	Quality Management of Mountain Watersheds	E. J. Middlebrooks Utah State University Utah Center for Water Resources Research Main Building, Room 104 Logan, Utah 84321	BOR Land Class V

The influence of recreational activities on delicate geological areas and the impact of recreational developments on watersheds are being quantified to help administer the watersheds for maximum use.

Three watersheds in various stages of use and development are being examined. The contribution of waste water treated effluents in recreational areas is being measured.

m)	Assessment of Man's Activities on the Lake Powell Region	R. C. Reynolds Dartmouth College School of Arts Hanover, N.H. 03755	BOR Land Class II

The nature of the physical and chemical changes taking place in Lake Powell are being examined for the purpose of estimating the future effect of these changes on the lake as an economic and recreational enterprise.

n)	An Investigation into Recreational Water Quality Criteria	L. A. Schinazi	BOR Land Class II

The objective of this study is the establishment of a scientific basis from which meaningful recreation water quality criteria can be formulated.

o) Environmental Planning for an Alaskan Water-oriented Recreational Area	D. W. Smith University of Alaska Institute of Water Resources Box 95103 Fairbanks, Alaska 99701	BOR Land Class II

This study will develop a water resources management and protection plan for a large water-based recreation area around Anchorage, Alaska. Use of the park for water-based recreation and camping will exceed 2,800,000 user-days by 1980. Water supply, limnology and hydrology studies will be used as guidelines for developing similar plans for other parks.

Hydrology patterns, soil characteristics and eutrophic levels of park waters are being measured together with public health aspects.

p) Water Quality Factors in a Watershed Used for Municipal Supply and Waste Disposal	D. G. Stuart Montana State University School of Letters Bozeman, Mont 59715 (Funded by NSF RANN Program)	BOR Land Class I

Studies are being conducted of recreational activity, logging and wildlife within a watershed used for municipal water supply and waste disposal.

Attempts are being made to differentiate indicator organisms and pathogens on the basis of their source: wildlife vs. agricultural vs. human. The effects of effluent from waste water treatment are being followed in order to relate them to the efficiency of the sewage treatment operation.

Improvement of routine recovery methods for indicator organisms from natural waters and waste waters are being sought, and the persistence of bacteria in natural waters is being determined.

q) Recreational Effects upon the Quality of an Impounded Water Supply	R. J. Wagenet University of Oklahoma School of Health Sciences Oklahoma City, Okla 73104	BOR Land Class II

Swimming, boating, waterskiing, picnicking and camping activities of 2,300,000 recreationers were studied for eight months on a 2,458 Ha (6,070 A) area. Peak use was at week-ends in summer. Parameters monitored were fecal coliforms, pH, turbidity, temperature and dissolved oxygen.

Recreation has a marked local effect in areas used for body contact activity. Fecal coliform counts were correlated to density and type of activity.

4.1.2 Studies Concerning the Impact of Recreation on Environmental Quality

a) The Impact of a Large Recreational Development upon a Semi-Private Environment--A Case Study	C. C. Bradley Montana State University School of Letters Bozeman, Mont 59715	BOR Land Class I

A multidisciplinary team has initiated a major socio-economic ecological study of the Gallatin Canyon area of Montana. Baselines were developed for use in measuring the impact of a large recreational development on environmental quality.

b) Title Unknown	R. Famun University of Minnesota Dept. of Soil Science St. Paul, Minn 55101	BOR Land Classes III and V

Research is being conducted on the use of peat for absorption of latrine wastes in wilderness campsites in the Great Lakes Basin.

c) Nutrient Runoff from Forest Lands	E. A. Hansen USDA Forest Service North Central Forest Experiment Station Cadillac, Mich	BOR Land Class III

P.I. was on annual leave.

d) Social and Ecological Problems of Northwoods Wilderness-type Recreation	M. L. Heinselman University of Minnesota USDA Forest Service North Central Forest Experiment Station St. Paul, Minn 55101	BOR Land Class V

The objective of this study is to improve the planning and management of recreational use of northwoods wilderness and related forest lands. The number of visitors and level of development an area can tolerate without excessive damage to the environment or the visitors' enjoyment are being measured. Parameters being examined are: 1) visitor use, 2) travel behavior, 3) number and types of visitor encounters, 4) reactions to encounters, and 5) perceptions of the maximum crowding which does not destroy a sense of wilderness.

e) Effects of Iron Shot on on Wildfowl Crippling	R. McCabe University of Wisconsin Dept. of Wildlife Ecology Madison, Wi 53706	

The efficacy of iron versus lead shot on kill, knockdown and crippling of ducks is being assessed from the standpoint of bird physiology.

f)	A Proposal for a Recreational Carrying Capacity and Economic Impact Study of the Sawtooth Valley	E. L. Michalson University of Idaho Water Resources Research Institute Moscow, Idaho 83843	

The objectives of this study are: 1) determine the recreational carrying capacity and related economic impact; 2) determine the biological carrying capacity of the water and land resources relative to vegetation, fisheries and wildlife; 3) determine physical carrying capacity of water and soils; and 4) determine capacity of area to retain its present aesthetic beauty and pastoral mountain valley character. The major emphasis will be to provide decision-making information for land managers.

g)	Ballistics of Iron Shot	E. Rosicky Conservation Section Winchester Western Arms East Allon, Ill (Industry funding)	

Phenomena associated with the use of iron pellets instead of lead for scattershot for wildfowl hunting are being studied. Spreading patterns, kinetic energy of the shot and gunbarrel wear are being determined.

h)	Gross Erosion Rates for the Upper Great Lakes Region	U. S. Soil Conservation Service	BOR Land Classes I-V

This is an ongoing monitoring program; cf. Section 4-1.6.

i)	Title Unknown	D. Prettyman USDA Forest Service Superior National Forest	BOR Land Class V

As part of an ongoing administrative study of land management, erosion rates have been measured at several wilderness forest campsites used by canoeists.

j)	Regional Park and Recreation Study	B. Rubin, Chief Land Use Planning S.E. Wisconsin Regional Planning Commission Old Courthouse P. O. Box 769 Waukesha, Wi 53186	BOR Land Class I

The Commission is studying runoff from urban parks as part of their program in planning regional parks, outdoor recreation and open space facilities.

4.1.3 Studies Concerning Bacterial and Viral Effects on Water Quality

a) Enteric Virus Survival

E. W. Akin
U.S. Environmental
Protection Agency
Gulf Coast Water Hygiene Lab
Dauphin Island, Ala 36528

This study has implications for the quality of swimming water quality.

b) Influence of Perceptions of Water Quality on Swimming

T. L. Brown
Dept. of Natural Resources
SUNY School of Agriculture
Ithaca, N.Y. 14850

A case study approach is being used to determine residents' perceptions of nearby waters for swimming, the degree to which their swimming participation is influenced by their perceptions of water quality, and how their perceptions compare to actual physical and biological measures of water quality and current swimming standards as established by local and state boards of health.

c) Relation of Swimming Water Quality to the Occurrence of Ear Infections

A. W. Hoadley
Georgia Institute of Technology
Atlanta, Ga.

Preliminary results of this study indicate that pseudomonads are important in swimming waters.

d) Epidemiological-Microbiological Trials on Pollution Arising from Recreational Areas

V. J. Cabelli
Recreational Water Criteria Program
N.E. Marine Health Sciences Lab
Narragansett, R.I. 02882

Previous studies on methodology for microbiological examination of recreational waters are being critically reviewed. Two papers are in press and two more are in preparation on the effect of bacteria from recreational activity on health.

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e) Relation of Swimming Water to Occurrence of Health Problems

J. Buck
University of Connecticut
Marine Research Lab
Noank, Conn 06340

No information available.

f) Survival of Intestinal Bacteria in Pristine Waters

D. L. Johnstone
Washington State University
School of Engineering
Pullman, Wash 99163

A comparison is being made of regrowth and die-off of pathogenic and non-pathogenic bacteria of intestinal origin in pristine waters. Samples have been collected from pristine streams over two years to encompass the annual water cycle. By bacteriological and chemical characterization, the kinetics of survival under various conditions are being studied.

Data should allow better evaluation of the fate of intestinal bacteria introduced into water by recreational use.

4.1.4 Studies Concerning Ecological Impacts of Off-road Vehicles

a) Ecological Impact of Snowmobiling in Northern Minnesota

W. J. Wanek
Bemidjii State College
Center for Environmental Studies
Bemidjii, Minn

BOR Land Classes I-IV

The project includes tests on conifer plots to determine the impact of snowmobiling on young trees and monitoring of forest species to determine if colder temperatures under snowmobile trails interfere with normal life cycles.

Tree and shrub communities are being studied to determine if snowmobiles are effective agents of vegetation control and to observe any changes in structure and composition with repeated usage.

The impact of snowmobiling on agricultural crops in different soils is being examined to see if impact differs with soil type.

These studies have implications for the question of whether snowmobiling causes accelerated soil erosion.

b) Model Recreation Vehicle Legislation

Larkin, Hoffman, Daly
and Lindgren, Ltd.
Minneapolis, Minn
Sponsored by Upper Great Lakes
Commission

Model legislation for all off-road recreational vehicles, except snowmobiles, is being drawn up. A review, summary and suggested changes of existing administrative rules for each state of the Upper Great Lakes Region are being made. Guidelines will be proposed for an interstate agreement on uniform administration and reciprocity regarding off-road recreational vehicles. Changes will be suggested in existing snowmobile laws and regulations.

c) Off-road Recreational Vehicle User Characteristics and Economic Impact

J. G. Bollinger
University of Wisconsin
Dept. of Mechanical
Engineering
Madison, WI 53706
(Funded by Wisconsin Public
Lands Commission)

BOR Land Classes I-IV

An analysis of off-road recreational vehicle users and of the economic impact of off-road recreational vehicles in the Upper Great Lakes Region is being conducted.

d) Snowmobiling

J. V. Hoene
Director of Public Affairs
International Snowmobile
Industry Association
5100 Edina Boulevard

Minneapolis, Minn 55435

A report is being prepared which will reflect the acreage of National Forest lands and the amount of acreage presently closed to snowmobile use on those lands.

e) Off-road Vehicles

C. T. Garrison
Executive Director
Texas Parks and Wildlife Dept.
Austin, Tex 78701

Specific areas and trails in a number of Texas State Parks have been opened on a trial basis to mini-bike use.

The physical effects on the environment and the psychological effects on users and non-users are being monitored. The effect on soil compaction, erosion, etc., is being measured. Use of all-terrain vehicles of low-tire-pressure type is being monitored in some wildlife management areas. Use is prohibited in areas with sandy soil.

A final policy decision as to the desirability of these types of vehicles will be determined some time in the future.

f) Off-road Vehicles (Including Snowmobiles)

D. M. Gates
University of Michigan
Douglas Lake Biological Station
Ann Arbor, Mich 48106

This study is examining the impact of snowmobiles and off-road vehicles on vegetation, soils and wildlife, especially with regard to soil erosion potential and soil movement and the consequences of snowpack modification on vegetation and soils.

Impact of summer off-road vehicles on physical and chemical properties of soils and on soil structure, vegetation and wildlife is being estimated, primarily on steep and unstable slopes, and in sandy, windy sites.

g) Snowmobile Study Project

J. Perry
Gogebic Community College

The exact nature of research has not been selected.

h) Off-highway Vehicle Study

W. Mott, Jr.
Dept. of Parks and Recreation
California Resources Agency
Box 2390
Sacramento, Cal 95811

This is an 18-month study started in October 1972. It will investigate the problems and potentials related to the use of all-terrain vehicles in California.

i) Effects of Motor Vehicle Closure on Game Populations

M. H. Peterson
Planning Officer
Arizona Outdoor Recreation Coordinating Commission
2222 W. Greenway Road
Phoenix, Ariz 85023

This study, to be completed in 1974, will determine the effect of motor vehicle exclusion from a Ponderosa Pine study area on deer and elk populations and on hunter use and success.

4.1.5 Studies of Pollution from Outboard and Marine Engines

a) Detection of Hydrocarbon Residues in Lakes

K. K. Andersen
University of New Hampshire
College of Technology
Parsons Hall
Durham, N.H. 03824

Hydrocarbon residues could be detected in lake water at a 10 μg/l, ppm level using methylene chloride extraction followed by gas chromatography of concentrated extracts. No attempt is being made to identify specific substances.

b) Pollution of Lakes by Watercraft Exhaust

L. N. Kuzminski
Univ. of Massachusetts
Dept. of Civil Eng.
Amhurst, Mass 01002

This project will evaluate the effect of exhaust on lake water quality. The type and quantity of lead, oxides of nitrogen, hydrocarbons, phenols, oil constituents and chemical oxygen demand will be determined. The effects on fish life and fish quality will be ascertained.

c) Effect of Exhaust from Two-cycle Outboard Engines

W. W. Shuster
Rensselaer Polytechnic Institute
School of Engineering
Troy, N.Y. 12181

Types and quantities of discharge into the surface, water column, sediments and littoral zone of an oligotrophic/mesotrophic lake are being measured, together with the kinetics of removal through microbial, absorptive and evaporative mechanisms.

The study will develop a loading estimate in terms of a boating-hour index.

d) Control of Pollution from Outboard Engine Exhaust

W. W. Shuster
Rensselaer Polytechnic Institute
School of Engineering
Troy, N.Y. 12181

This study will quantify the extent of water pollution from outboard engines used on pleasure craft and demonstrate use of an emission prevention device. The distribution of organics will be measured in a controlled laboratory ecosystem with and without the device.

e)	Engineering for Ice and Its Action on Small Craft Marinas	J. Zarling University of Wisconsin Dept. of Engineering Whitewater, WI (Funded by Sea Grant Program)

This study is designed to find methods of curtailing ice damage in marinas. This information will help reduce shore bank erosion.

4.1.6 Miscellaneous

a)	Animal Waste Disposal	Hamilton Standard

This study of disposal of animal waste could have implications for riding stables.

b)	Water Law in Relation to Environmental Quality with Particular Reference to Recreational and Aesthetic Values	G. A. Swanson Colorado State University School of Forestry Fort Collins, Colo 80521

A study is being conducted of the effectiveness of constitutional and statutory water laws and regulations in protecting the quality of water resources as they relate to recreational and aesthetic values.

States will be studied in relation to their effectiveness. Representative eastern and western states will be visited and studied in depth.

c)	Advisory Services Program	R. A. Ragotzkie University of Wisconsin Sea Grant Program 1225 W. Dayton Street Madison, WI 53706

One area being studied covers the recreation industry and related government planning. The aim is to develop and expand information channels between user groups and the U.W. Sea Grant Program to identify problem areas and deliver useful information to the industry.

d)	Study of Marine Sanitation Devices	Edison Water Quality Research Edison, N.J. Industry Funds

Devices such as macerator-chlorinators for use on existing vessels and holding tanks for new vessels are being tested.

4.1.7 Water Quality Monitoring

A number of federal and state agencies and industrial companies monitor water quality in the Basin on a continuous or periodic basis. All of the information obtained is supplied to the USDI Geological Survey Office of Water Quality Data Coordination, which collates the findings and publishes the data in tabular form (257). A list of the participating organizations is given in Table 24.

In addition, sedimentation measurements, including determination of the concentration and particle size distribution of suspended solids, and the particle size distribution of bed deposits, are being conducted in 47 sites in the Basin. Earlier data are available for 13 further sites, where measurements have now been discontinued. Data for some years are unavailable at 6 sites, where measurements were temporarily discontinued. The location of the monitoring sites, the parameters examined, the frequency of measurement and other relevant information are summarized in Table 25.

TABLE 24

Agencies monitoring water quality for the Great Lakes Basin and supplying data to the Office of Water Data Coordination, Geological Survey, U. S. Department of Interior

FEDERAL AGENCIES

Atomic Energy Commission
Environmental Protection Agency
Forest Service (Agriculture)
Geological Survey (Interior)
National Facilities Engineering Command (Navy)
National Ocean Survey (Commerce)
National Weather Service (Commerce)
Bureau of Sport Fisheries & Wildlife (Interior)

NON-FEDERAL AGENCIES

Illinois

Environmental Protection Agency, Division of Water Pollution Control
Metropolitan Sanitary District of Greater Chicago
Illinois Department of Public Works and Buildings

Indiana

Indiana State Board of Health

Michigan

Michigan Department of Natural Resources

Minnesota

Eveleth Taconite Company
Division of Waters, Soils and Minerals, Minnesota Conservation Department
Water and Gas Department, City of Duluth
Minnesota Ore Operations, USS Corporation
Minnesota Power and Light Company, Duluth
Minnesota Pollution Control Agency, Division of Water Quality

New York

New York State Department of Environmental Conservation

Ohio

Ohio Department of Health

Pennsylvania

Pennsylvania Department of Environmental Resources

Wisconsin

Wisconsin Department of Natural Resources
Wisconsin Michigan Power Company

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Table 25. Location and frequency of sedimentation measurement in the Great Lakes Basin (after 246).

MAP		OWDC NUMBER	AGENCY STATION NUMBER	STATION NAME	LATITUDE	LONGITUDE	STATE	COUNTY	SITE	PERIOD OF RECORD		INTERRUPTED RECORD	SEDIMENT				AGENCY REPORTING
NUMBER	LETTER									BEGAN	DISCONTINUED		CONCENTRATION (SUSPENDED)	PARTICLE SIZE (SUSPENDED)	PARTICLE SIZE (BED MATERIAL)	OTHER	
21	Y	50509	04201500	ROCKY R NR BEREA OHIO	412422	0815313	OH	035	STREAM	1964			4	8	8		GS
21	Y	50508	04200500	BLACK R AT ELYRIA OHIO	412250	0820615	OH	093	STREAM	1962			8	8	8		GS
21	Z	50517	04208000	CUYAHOGA R AT INDEPENDENCE OHIO	412344	0813745	OH	035	STREAM	1948			3	8	8		GS
21	AA	50523	04212500	ASHTABULA R NR ASHTABULA OHIO	415119	0804543	OH	007	STREAM	1965			8	8	8		GS
21	AA	50521	04212000	GRAND RIVER NR PADISON OHIO	414426	0810248	OH	085	STREAM	1965			8	8	8		GS
21	AA	50518	04209000	CHAGRIN R AT WILLOUGHBY OHIO	413751	0812413	CH	085	STREAM	1965			4	8	8		GS
21	AB	50524	04213000	CONNEAUT C AT CCNNEAUT OHIO	415534	0803618	OH	007	STREAM	1965		•	8	8	8		GS
21	AC	50507	04199500	VERMILICN R NR VERMILION OHIO	412255	0821900	OH	093	STREAM	1950		•	8	8	8		GS
21	AC	50506	04199000	HURON R AT MILAN OHIO	411800	0823630	OH	043	STREAM	1950		•	8	8	8		GS
22	S	51813	04100500	FLKHART R AT GCSHEN IND	413536	0855055	IN	039	STREAM	1963	1968		•	•			GS
22	O	54386	04142000	RIFLE R NR STERLING MI	440421	0840112	MI	011	STREAM	1966	1968		4	8			GS
22	Q	54389	04151500	CASS R AT FRANKENMUTH MICH	431950	0834525	MI	145	STREAM	1966			4	8			GS
22	T	54388	04144500	SHIAWASSEE R AT CWCSSC MICH	430010	0841115	MI	155	STREAM	1966			4	8			GS
22	W	54390	04159500	BLACK R NR FARGC MICH	430532	0823705	MI	147	STREAM	1966	1970		4	8			GS
22	X	54392	04164000	CLINTON R NR FRASER MICH	423440	0825700	MI	099	STREAM	1966	1970		4	8			GS
22	Y	55081	32903 04165700	DETROIT R AT DETROIT MICH	422C5C	0825731	MI	163	STREAM	1957			•				EPA
22	AB	54393	04176500	R RAISIN NR MONROE MICH	415750	0833155	MI	115	STREAM	1966			4	8			GS
22	AE	51814	04182000	ST MARYS R NR FCRT WAYNE IND	4C5916	0850603	IN	003	STREAM	1953	1968		•	•			GS
22	AF	50883	04185000	TIFFIN R AT STRYKER OHIO	413015	0842550	OH	171	STREAM	1952		•	8	8	8		GS
22	AG	50887	04189000	BLANCHARD R NR FINCLAY OHIO	410321	0834117	CH	063	STREAM	1965			8	8	8		GS
22	AH	50889	04191500	AUGLAIZE R NR DEFIANCE OHIO	411415	0842357	OH	C39	STREAM	1965			8	8	8		GS
22	AH	50885	04186500	AUGLAIZE R NR FT JENNINGS OHIO	405655	0841558	OH	137	STREAM	1965			8	8	8		GS
22	AI	50892	04193500	MAUMEE R AT WATERVILLE OHIC	413000	0834246	OH	095	STREAM	1950			3	8	8	•	GS
22	AK	50501	04197000	SANDUSKY R NR MEXICC OHIO	410239	0831142	OH	147	STREAM	1965		•	8	8	8		GS
22	AK	50500	04196800	TYMOCHTEE C AT CRAWFORD OHIO	405520	0832100	OH	175	STREAM	1965			8	8	8		GS
22	AK	50897	04196000	SANDUSKY R NR BUCYRUS OHIO	404813	C830024	OH	033	STREAM	1965			8	8	8		GS
23	K	51203	04063700	POPPLE R NR FENCE WIS	454550	0882750	WI	037	STREAM	1963			4	7			GS
23	K	51202	04061000	BRULE R NR FLORENCE WIS	455731	0881557	MI	071	STREAM	1964	1968		8				GS
23	K	51204	04066000	MENOMINEE R NR PEMRINE WIS	453525	0874635	MI	109	STREAM	1964			•				GS
23	K	54368	04062400	MICHIGAMME R NR WITCH LAKE MICH	461448	0880045	MI	043	STREAM	1964			•				GS
23	O	51205	04080000	LITTLE WOLF R AT RCYALTON WIS	442445	0885155	WI	135	STREAM	1963	1970		•				GS
23	O	56322	04081000	WAUPACA R NR WAUPACA WIS	441950	0885945	WI	135	STREAM	1963	1971		•				GS
23	O	65484	04072750	LAWRENCE C NR WESTFIELD WIS	435352	0893452	WI	077	STREAM	1967			•	•	•		GS
23	O	67735	04073500	FOX R AT BERLIN WIS	435715	0885710	WI	047	STREAM	1967			•				GS
23	R	67734	04085200	KEWAUNEE R NR KEWAUNEE WIS	442730	0873323	WI	061	STREAM	1968			5	8	8		GS
26	A	51206	04086000	SHEBOYGAN R AT SHEBOYGAN WIS	434425	0874535	WI	117	STREAM	1963			•				GS
26	B	51207	04087000	MILWAUKEE R AT MILWAUKEE WIS	430600	0875430	WI	079	STREAM	1963			5	8	8		GS
26	R	67732	04086200	E B MILWAUKEE R AT NEW FANE WIS	433301	0881118	WI	039	STREAM	1968			5	8	8		GS
26	B	67731	04086340	N B MILWAUKEE R NR FILLMORE WIS	432858	0880339	WI	131	STREAM	1968			5	8	8		GS
26	R	67730	04086360	MILWAUKEE R AT WAUBEKA WIS	432822	0875923	WI	089	STREAM	1968			•				GS

Table 25 (continued)

MAP		OWDC NUMBER	AGENCY STATION NUMBER	STATION NAME	LATITUDE	LONGITUDE	STATE	COUNTY	SITE	PERIOD OF RECORD		INTERRUPTED RECORD	SEDIMENT				AGENCY REPORTING
NUMBER	LETTER									BEGAN	DISCONTINUED		CONCENTRATION (SUSPENDED)	PARTICLE SIZE (SUSPENDED)	PARTICLE SIZE (BED MATERIAL)	OTHER	
26	B	67718	40865	CEDAR R NR CEDARBURG WIS	431925	0875848	WI	089	STREAM	1968	1971		●				GS
26	C	73122	04087257	PIKE R NR RACINE WIS	423849	0875130	WI	059	STREAM	1971			5	8	8		GS
26	C	51209	04087240	ROOT R AT RACINE WIS	424505	0874925	WI	101	STREAM	1964			5	8	8		GS
26	C	51208	04087220	ROOT R NR FRANKLIN WIS	425225	0875945	WI	079	STREAM	1964			5	8	8		GS
27	A	51200	04025500	BOIS BRULE R AT BRULE WIS	463215	0913545	WI	031	STREAM	1964			8				GS
27	A	73123	04026005	BOIS BRULE R NR L SUPERIOR WIS	464220	0913607	WI	031	STREAM	1971			5	7	7		GS
27	A	67729	04026300	SIOUX R NR WASHBURN WIS	464120	0905702	WI	007	STREAM	1968			8				GS
27	A	57119	NE-8	NF NEMADJI R	463107	0922322	MN	017	STREAM	1967	1968					5	LII
27	B	51201	04027000	BAD R NR ODANAH WIS	462915	0904145	WI	003	STREAM	1964			5				GS
29	A	54362	04001000	WASHINGTON C AT WINDIGO MICH	475523	0890842	MI	083	STREAM	1964			8		7		GS
29	A	63278	04014500	BAPTISM R NR BEAVER BAY MINN	472C15	0911200	MN	075	STREAM	1962		●	●	●			GS
29	B	72871	SLB 0	SUPERIOR BAY LIFT BRIDGE			MN	137	STREAM	1971						5	LII
29	D	63279	04018750	ST L [illegible] AT FORBES MINN	472148	0923556	MN	137	STREAM	1967	1971		5	7			GS
29	D	57120	SL-19.1	SAI [illegible] UIS R	463910	0921655	MN	137	STREAM	1953						5	LII
29	D	57122	SL-120	SAI [illegible] LOUIS R	472147	0923550	MN	137	STREAM	1967	1968					5	LII
29	D	57121	SL-51.9	SAINT LOUIS R	465C5C	0923434	MN	137	STREAM	1962						5	LII
80	A	57123	LS-3	LAKE SUPERIOR	465154	0915730	MN	137	LAKE	1967	1968					5	LII
90	A	57124	LS-2	LAKE SUPERIOR	471810	0911407	MN	075	STREAM	1967						5	LII
80	A	57125	LS-1	LAKE SUPERIOR	474411	0902314	MN	031	LAKE	1967						5	LII
80	B	55958	6373-496	LK MICHIGAN GREAT LAKES ILL	421847	0874809	IL	097	LAKE	1960			3				NFE

Key: Map numbers and letters refer to the location of the station in the geographic units and subunits system used by the OWDC (Office of Water Quality Data Coordination, USDI Geological Survey).

Agency Station numbers are used by OWDC for information retrieval purposes.

In station names, R = river, NR = near, EB = east branch, NB = north branch

Latitude and longitude are given in degrees/minutes/seconds north of equator and west of Greenwich.

County numbers refer to the OWDC alphabetical list of counties.

Numbers in the sediment column refer to frequency of monitoring: 3 = daily, 4 = weekly, 5 = monthly, 7 = annually, 8 = periodically.

Reporting agency abbreviations: GS = USDI Geological Survey, EPA = Environmental Protection Agency, LII = Minnesota Pollution Control Agency, NFE = U.S. Dept. of Navy National Facilities Engineering Command

Section 5

NATURE AND AVAILABILITY OF TECHNOLOGY TO COPE WITH RECREATION-RELATED POLLUTION PROBLEMS

5.1 Nature of Technology and Examples Where Practiced

5.1.1 Preamble

Most outdoor recreational pursuits are comparatively free of technological attachments, while a few, e.g. snowmobiling and waterskiing, were exclusively created by technology. For this reason, the following discussion is divided further into subsections, first dealing with technologies affecting specific recreational activities which were initiated by technology and which are therefore most subject to technological manipulation, and then technologies which are used to create and sustain the general recreational environment.

5.1.2 Boating Technology

The overwhelming majority of boat engines in use today are two-cycle outboards (194), which discharge exhaust gases and, in older models, excess unburned oil-gas mixture directly into the water (152). Newer engines recycle this excess back into the combustion chamber (21,197, 237). All new outboard engines have an improved crankcase design which reduces pollution (21,197,237). However, the majority of outboards still in use are of the old type and could be converted to the more efficient mode of operation (36). The existing technology of direct discharge of exhaust gases into the water does not severely affect water quality and lake life at the present levels of boating (151,205,223).

Another pollution load from boating has been associated with direct discharge of human waste into streams and lakes (cf. Section 3.4.3). On-board holding tanks and treatment systems are now being developed which offer a satisfactory solution to this problem. By 1980, all boats will be required to have on-board holding tanks or incinerators which will eliminate any discharge. The on-board waste will be pumped out and treated as ordinary domestic waste; residual ash from incinerators will be also disposed of onshore (56,114,115,221,225).

5.1.3 Snowmobile Technology

The primary environmental impact of the snowmobile involves its effects upon the underlying running surface (cf. Section 3.4.4). Since this interface seems to be largely unalterable and is determined primarily by the highly variable factor of snowcover, proper management practice is the best method of minimizing environmental damage. Modification of the weight, drive and runner characteristics of the vehicles would not necessarily bring improvements.

Exhaust from snowmobiles has not yet been assessed to be a serious pollution problem; it is only a small percentage of the total from all sources (152). It may have effects upon pollutant accumulation on winter lakes (205). Improved emission control is possible but has not yet been deemed necessary.

Noise pollution (37) is the most serious effect of snowmobiles. A simple technological solution is available in the form of better mufflers, but there is as yet no specific regulation of snowmobile noise.

5.1.4 Other Off-road Vehicles

The main impact of ORRVs is upon the terrain (cf. Section 3.4.5). Good trail management in areas of operation and user educational programs could best counteract deleterious effects. Modifications of vehicle weight and tire profiles cannot substitute for responsible use. Noise pollution can be countered with quieter mufflers.

5.1.5 Golf Courses

Golf course runoff is high in nutrients and contains mercury from pesticide compounds used for turf management (90). Chemical technology is available to develop less hazardous fungicides. Available technology could solve nutrient loss by introducing holding ponds into golf course drainage patterns. Organic rather than inorganic fertilizers would reduce nitrogen losses. Suitable soil mixes in greens would reduce phosphorus leaching losses.

Management practices might be improved by educating green superintendants to apply anti-pollution techniques, and to base their green fertilization programs on need, as indicated by soil testing. The Greens Service of the U.S. Golfing Association cooperates with greens superintendants in setting up suitable programs for greens maintenance.

5.1.6 Hunting

Lead shot pellets have been shown to cause enormous casulties among ducks by lead poisoning (cf. Section 3.4.6). While gross amounts of lead are not high, the shot is concentrated in choice wildfowl habitats, where chances of ingestion are high. A technological solution to this problem is being sought in the form of a suitable substitute for conventional lead shot.

5.1.7 General Recreational Environment

Ability to deal with pollution is dependent on our total technological capability. In the recreational area, both management and monitoring technologies are as important as engineering technologies in controlling pollution. Examples of good management technologies include provision of solid and sewage waste treatment systems, septic tank system, erosion control and watershed management. Septic tank systems are generally employed where city sewer facilities are lacking; they have great value to the recreationist because they allow him to enjoy a choice recreational site without losing any comfort in his living arrangement. By placing systems of proper dimensions on appropriate soils at appropriate distances from lakes or watercourses, the effects of these systems on water quality can be minimized (cf. Section 3.4.7). Soil erosion control and watershed management are especially important when developing recreational areas. Used properly, these techniques can save much top soil and sediment from being washed away during development and prevent accelerated losses during subsequent recreational area use. Such simple measures as the seeding of ski slopes have saved valuable top soil and preserved choice recreational sites for both summer and winter enjoyment (cf. Section 3.4.12).

5.2 Recommended Priorities for Adopting Technology

In this technological age, the time between discovery of a new technology and its widespread deployment is ever shortening. There is however, some technology available that is not now being used extensively enough for pollution abatement. Although there are many useful tools that could be used to thwart pollution, some are not being used as widely as desirable from the environmental standpoint because of poor acceptance by consumers. If educational programs fail to bring changes in user habits, legislation might be warranted in some instances to assure adoption of novel technological systems. For example, improved septic systems should be installed in areas where existing facilities, built before adoption of current codes, are known to be unsuitable. Provisions should be made to ensure that boats and snowmobiles use only unleaded fuels. Improved designs for lakefront developments (such as ones allowing a "natural zone" around the shoreline), and other recreational facilities should be applied when new recreational areas are developed.

Current listings of water quality programs and sites (246,257) indicate that there may be some deficiencies with regard to the number of recreation-related monitorings, the frequency of sampling and the types of pollutants examined. Closer examination of sedimentation rates from high-density recreational lands may reveal needs for greater erosion control. Suitable measures can be rapidly implemented in problem areas. Monitoring of the bacterial and nutrient contents of groundwater near large unsewered recreational facilities and of recreational waters during periods of peak use should be conducted to establish whether health hazards exist that can be corrected by appropriate management technology.

To combat litter, whenever possible biodegradable containers should be used for materials sold in recreational areas and such incentives as deposits on returnable bottles should be used.

5.3 Need for New Technology

There are certain areas where new information is needed together with its subsequent application to new management technologies. Studies must be undertaken to develop a meaningful correlation between the presence of coliforms and real health risks from pathogens in recreational waters. There seems to be broad agreement that present methods are inadequate but that with additional work, a much more accurate correlation could be developed and used in swimming area management. New culturing techniques for detecting and isolating pathogens, which are present only in extreme dilution, are needed.

New methods are needed for constructing recreational facilities on unstable or problem soils in order to minimize pollution resulting from erosion or poorly functioning septic tank systems.

Lastly, new technologies are needed for eliminating nitrate and phosphate flow into groundwater or surface waters from non-sewered recreational areas and from overfertilization of turfgrasses on recreational sites (golfgreens, playing fields).

Section 6

NEED FOR NEW RESEARCH, DEMONSTRATION OR MONITORING PROGRAMS

6.1 Gaps in Knowledge Likely to be Remaining by 1976

Considering that the total impact of recreation on the overall picture of water quality appears to be relatively insignificant compared to most point sources of pollution and several other diffuse sources of pollution, there are no critical areas of concern that require immediate attention in the form of a concentrated crash program of research. It is nonetheless probable that there will still be minor gaps in knowledge remaining by 1976 which are relatively important within the framework of recreation itself. Information on these unresolved questions could provide methods of alleviating the more serious influence that recreation presently exerts on water quality. Although some of those areas are currently being researched (cf. Section 4), it is unlikely that all the problems will be satisfactorily resolved within the next several years.

The major problems are most likely to be associated with sewage disposal at non-sewered sites, including non-sewered residences, recreational resorts and campgrounds, and boat sewage treatment facilities. Although extensive research has been (42,85,86,127,146,155,165, 175,177,179,209,224,239,263,271) and is being conducted (22,46,51,183, 184,192,201,204,208,261,262) on the subject, the problem of failure of septic-tank/soil purification systems has not yet been satisfactorily dealt with, and there is no assurance that a solution will be found by 1976. The associated problem of leaching of nitrate from septic tank effluent seepage beds (34,54,158,188,211) is also likely to remain unresolved. Despite research efforts (240,261,262), no efficient method has yet been found either for destroying this assimilable fixed form of nitrogen by microbial denitrification or for immobilizing it in the soil seepage bed by absorption before it reaches the aquifer or surface waters. Since the same problem also exists with land disposal of sludge from metropolitan sewage treatment plants, this question is being intensively researched, but failing some unforeseen major breakthrough it is unlikely that a satisfactory solution will be found soon.

A third question unlikely to be answered by 1976 concerns the quality of water for recreational use and the need for better indicator organisms for assessing health hazards to swimmers (cf. 149). Although massive efforts have already been invested in the area of bacteriological pollution of recreational waters (45,57,58,87,98,105,112,116,129,144,148 169,180,181,185,186,193,215,218,225,230,236 and earlier references cited in these papers), it is still a moot point whether the current standards (8,26-32) are serving a useful purpose in public health protection, or are too restrictive, eliminating some swimming areas from use that are actually safe. Many scientists working in this area would prefer to see standards based on actual pathogen counts, rather than on fecal indicator organisms, which are of themselves harmless. The deterrent to this development is the difficulty involved in isolating the pathogens, which are present only in low dilution in a multitude of other organisms. More selective media and sample fractionation techniques will have to be evolved before reliable test methods can be worked out.

6.2 New Studies Required to Define Remaining Problems

6.2.1 Basic Research

In addition to the problems just discussed, which are being researched at the moment, other potential areas of concern can be identified which can be brought into perspective by simple basic research studies.

Although most evidence seems to suggest that long-chain aliphatic hydrocarbons deposited in water from boat-engine fuel losses or incomplete fuel combustion are apparently biodegradable in warmer water during the boating season (4,6,33,93,103,134,151,152,159,173,194,205,223), it is as yet unclear whether hydrocarbons deposited by vehicles traversing frozen lakes in winter remain undecomposed. Moreover, it is unknown whether carcinogenic polycyclic aromatic hydrocarbons deposited in water by engine exhaust (151) persist and accumulate, and constitute a latent health hazard. Similarly other carcinogens such as nitrosophenols produced by nitrogen oxides from underwater engine exhaust or chloramines resulting from water disposal of chlorinated wastes from onboard or onshore boat sewage treatment might affect water quality, especially in areas where recreational waters also serve as a source of drinking water. It is also unknown whether viruses can occur and persist in recreational waters and constitute a health hazard. Viruses could be deposited in water by swimmers or enter through porous soils or creviced bedrock from latrines or septic sewage systems located too close to swim areas.

Additional basic information would also be useful for determining the extent of sediment loss from high-use recreational sites, especially sites located on or close to lakes. Known data (121,246) and additional measurements could be correlated with values computed by the universal soil loss equation (229) $A = R \cdot K \cdot L \cdot S \cdot C \cdot P$

where A = soil loss per unit area
R = the rainfall factor
K = the soil-erodibility factor
L = the slope length factor
S = the slope-gradient factor
C = the cropping management factor
P = the erosion control practice factor

to determine how accurate the equation is when applied to individual recreational sites. If good agreement is found, the equation could then be used as a guide for erosion control practice in recreational site management. The variability in soil loss with use intensity should be determined. Since erosion control measures for recreational areas should be designed to cope with peak visitor loads rather than average use levels, this correlation would be useful for assuring adequacy of management

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programs. This would help circumvent problems that might be caused by occasional extremely heavy use of some areas, such as the Eagle River area in northern Wisconsin during snowmobile championship meets. Analogously, basic information on the levels of nutrients and bacteria in waters close to campsites, recreation resorts, etc. at periods of peak use would establish the adequacy or inadequacy of sewage treatment facilities in such areas and indicate whether better or larger capacity facilities, or disposal site relocation would be desirable. This kind of information would also assist in planning the size, type and location of sewage treatment facilities at sites to be developed to meet future needs.

6.2.2 Demonstration and Monitoring Projects

Since water pollution caused by recreational activities appears to become serious or critical only in restricted heavily overused areas, it is important to determine the effective carrying capacity of recreational lands and waters. It is important to correlate the physical use capacity and limitations of the resource with the satisfaction of the recreational experience of the site users and the environmental consequences of overuse. This necessitates correlation of statistics on visitor volume at heavily used individual sites with water quality monitoring and sedimentation measurements. At present, routine water quality (257) and erosion (246) determinations are seldom specifically directed toward heavily used recreational areas, or toward periods of peak use. Closer coordination of these activities or improved interpretation of data already available would assist in determining optimum and maximum loading capacities for high density recreation areas.

There are numerous instances on the frontier of new and developing technologies where demonstration projects could serve to provide guidelines for future practice. Many such projects could be included within the ongoing management programs of federal and state governmental agencies or of private enterprises presently catering to recreational needs. Areas of major interest would include the following:

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1. demonstrate installation and operation of unsewered waste treatment facilities at heavily used recreational resorts, campgrounds, ski areas or public parks; systems should be shown to be capable of handling highly variable loads without significant loss of nutrients or biological pollutants to nearby waters, regardless of season, precipitation and other physical and environmental factors;

2. demonstrate safe installation of high-intensity recreational sites and buildings on unstable soils, e.g. in red clay districts or at highly frequented campsites in wilderness areas;

3. demonstrate efficient systems for onshore pumpout and treatment of boat sewage wastes;

4. demonstrate sound methods for handling and disposal of stable wastes this could be part of program of demonstrations of disposal of solid wastes from other domestic animals, e.g. dairy cattle;

5. demonstrate ideal methods of managing high-density recreational areas, including such aspects as lawn management with fertilization and mowing only according to need, trail construction, minimum pesticide use, shrubbery and tree management, toilet facilities and litter control;

6. demonstrate good golf course management, including soil testing prior to fertilizer application, use of organic rather than inorganic fertilizers, use of proper soil mixes for tee and green construction, use of catchment ponds for runoff and use of biodegradable organic fungicides rather than mercurials or arsenicals.

Finally, as part of the total process of recreational land and water management in the Basin, statistics should be collected on the influence of some practices on distributing use among recreational areas. Good distribution of recreational loads among the available resources help to reduce the hazard of localized pollution problems caused by overuse. Measures such as the levying of admission fees, requirements for advance reservations for overnight users, improvement of public transportation to more remote areas and the distribution of information on recreational facilities--both public and private--within certain regions can help reduce the loads on overused sites. There is already a great imbalance between the use of the larger more remote recreational areas, which tend to be underused and the smaller areas close to urban centers, which are generally overused. It appears likely that gasoline shortages and increasing gasoline prices will accentuate this imbalance even further, so that other incentives or constraints will have to be introduced to offset their effect, thus promoting equalization of loading of recreational lands and waters and minimizing the impact of recreational activities on Great Lakes Basin water quality.

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Section 7

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Land Use/Water Quality Relationships in the U. S. Great Lakes Basin
Task A: To assess problems, management of programs and research...
Category A12 - Undeveloped Land

UNDEVELOPED LAND

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August 1974

FRONTISPIECE

Tahquamenon Falls, Michigan.
Natural tannin-bearing water draining from
muskeg bogs in Michigan's Upper Penninsula.

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Section 1

SUMMARY

1.1 Introduction

The Great Lakes Basin has undergone a tremendous change in land use in the past 150 years. Nearly half of the landscape has been transformed from forests, prairies and wetlands to farms, cities, and industrial areas. The objective of this section is to discuss the relationships between the remaining undeveloped lands in the Basin and water quality in the boundary waters in the Great Lakes.

Undeveloped or natural areas predominate in the basins of Lakes Superior and Huron and major portions of the basins of northern Lake Michigan and eastern Lake Ontario. The Lake Erie Basin is highly developed with only 26 percent in undeveloped lands. The pollutants contributed from these areas consist of dissolved substances leached from the rock and soil, suspended natural material, plant detritus and animal wastes.

1.2 Summary of Findings and Conclusions

The landscape of the Great Lakes Basin and the formation of the Great Lakes themselves owe their present form to the molding action of the continental glaciers of the Pleistocene era. Innumerable lakes, marshes, and bogs mark places where the glacier gouged the rock, or blocked older drainage with debris, or left a stranded ice block partly buried in an outwash apron. Moraines, formed of ridges of mixed glacial debris, stretch across the Basin and mark the forward positions of the glaciers. Behind them lie striated bedrock and deposits of glacial till (14).

In the several thousands of years since glaciation, soil zones have formed in the Basin from this wide variety of parent material. Prior to 1820 when the first land settlement began in the Basin, nearly all of the area was forested except for small cultivated areas near Indian villages. The southern half of the lower peninsula of Michigan, northwestern Ohio, Indiana and southern Wisconsin had several small open prairies that later became focal points for early settlements. Most of the remaining land was covered with mixed hardwoods, primarily maple, beech, hickory, elm, ash and basswood. Forests containing pines were found in some parts of southern Michigan, for example, in the Saginaw Valley and in sandy areas along Lake Michigan. Pine was the most common component of the forests in the northern two-thirds of Michigan, northern Wisconsin and east central Minnesota where they were found associated with stands of other conifers and hardwoods (14).

First logging, then agriculture, and now industrialization and urbanization greatly reduced these forests throughout most of the Basin and have virtually eliminated the natural prairies. Today only 46 percent of the Basin is forest land (developed and undeveloped) and much of that has been lumbered at one time or another in the past 150 years. Other undeveloped areas, including wetlands and uplands, amount to only 9 percent of the Basin.

The leaching or weathering rates of chemicals from the natural terrain of the Great Lakes Basin has been derived from historical records (3 and 54) and by direct observations (13). The following comparison of dissolved solids loads to the Great Lakes shows the results of man's activities (54):

Lake	Natural	Cultural
Superior	87%	13%
Michigan	63%	37%
Huron	-	-
Erie	47%	53%
Ontario	38%	62%

Lakes Superior and Huron show the least changes in loading and weathering rates. For these two lake basins, chemical weathering rates are approximately 4×10^4 kg/km^2/yr (22.8×10^4 lb/mi^2/yr). Lakes Michigan, Erie and Ontario receive significant cultural loads. The total loads received by each of the Great Lakes have increased by factors of 1.5 to 10 in the past 100 years which can be interpreted as cultural loading.

Other significant forms of natural pollution include stream bank and lake shore erosion, biological debris such as leaves, fallen trees and other detritus, and atmospheric contributions such as dust and other suspended material. Taken together these account for approximately 10 to 15 percent of the total suspended material delivered to the lakes.

1.3 Recommendations

Although some models have been developed, particularly for natural weathering and forest ecosystems, many aspects of natural pollution are imperfectly known. The fate of natural organic compounds and role in ecosystem of the lakes deserves attention. Mechanical means have been used to remove debris and dredge sediment from harbor areas but no effective upland or water treatment controls have been devised to cope with these problems.

Section 2

SUPPORTING MATERIAL

2.1 Introduction and Scope

The Great Lakes Basin was molded into its present form by pleistocene glaciers. This unique method of formation characterized the Great Lakes topography with certain soil conditions. The soils range from sandy loam to loamy sand types (14). Each soil type contributes a natural input to the watershed in which it is located. Depending on the soil type this can range from a high hydrogen ion concentration to a high nitrogen, calcium or magnesium input to the Great Lakes (35). Other sources of impurities are precipitation (46) and the geologic character of the bedrock (35). The problem of natural contributions from the watershed began with the formation of the area and will always be a contributing factor although land use can dwarf the natural input.

The literature reviewed includes data from 1845 to the present.

2.2 Study Procedure

Information on natural pollution was acquired by: 1) interviewing university faculty members; 2) correspondence to federal and state agencies and universities; and 3) reviewing the literature.

Interviews were conducted with Ohio State University professors in geology, botany and limnology and with the agricultural extension agent located on campus. A number of additional interviews were conducted by telephone.

Written contact was made with: the Cooperative Extension Service, Pennsylvania State University; Agricultural Experimental Station, Michigan State University; Scientific Areas Preservation Council, Madison Wisconsin; Red Clay Interagency Committee, Madison, Wisconsin; Agricultural Experimental Station, Illinois; Michigan Natural Areas Council, Michigan; and Cooperative Extension Service, Indiana.

The literature sources reviewed include: 1) The Great Lakes Framework Study; 2) Proceedings, Great Lakes Research Conferences; 3) Federal Water Pollution Control Administration; 4) U.S. Environmental Protection Agency; and 5) pertinent journals and other government publications.

Six major assumptions were made.

1. Undeveloped or forested land and waterbodies greater than forty acres are natural areas.
2. Therefore, any impurities in the water draining from these areas would be of a natural origin and not man induced.
3. Probable that chemical levels of the Great Lakes prior to the twentieth century indicate steady state concentrations of natural pollutants (Upchurch, 54).

4. Similar natural areas located in the northeastern United States are subject to the same type of pollution as natural areas in the Great Lakes Basin, therefore data from these areas have been extrapolated to the Great Lakes region.

5. Because sediments are being considered separately in Section 7, they are not included as natural pollutants in this Section.

6. Only the United States portion of the Great Lakes Basin is considered in this Section. A list of the counties within the Basin follows:

- Illinois
  - Cook
  - DuPage
  - Lake
  - Kane
  - McHenry
  - Will
- Indiana
  - Adams
  - Allen
  - DeKall
  - Elkhart
  - LaGrange
  - Lake
  - LaPorte
  - Marshall
  - Noble
  - Porter
  - St. Joseph
  - Steuben
- Michigan
  - Alcona
  - Alger
  - Allegan
  - Alpena
  - Antrim
  - Arenac
  - Baraga
  - Barry
  - Bay
  - Benzie
  - Berrien
  - Branch
  - Calhoun
  - Cass
  - Charlevoix
  - Cheboygan
  - Chippewa
  - Clare
  - Clenton
  - Crawford
  - Delta
  - Dickinson
  - Eaton
  - Emmet
  - Galdwin
  - Genesee
  - Gogebic
  - Graliot
  - Grand Traverse
  - Hillsdale
  - Houghton
  - Huron
  - Ingham
  - Ionia
  - Iasco
  - Iron
  - Isabella
  - Jackson
  - Kalamazoo
  - Kent
  - Keweenaw
  - Lake
  - Lapeer
  - Leelanau
  - Lenawee
  - Livingston
  - Luce
  - Mackinac
  - Macomb
- Michigan (cont.)
  - Marquette
  - Mason
  - Mecosta
  - Menominee
  - Midland
  - Missaukee
  - Monistee
  - Monroe
  - Montclam
  - Montmorency
  - Muskegon
  - Newaygo
  - Oakland
  - Oceana
  - Ogemaw
  - Ontonagon
  - Osceloa
  - Oscoda
  - Otsego
  - Ottawa
  - Presque Isle
  - Roscommon
  - Saginaw
  - St. Clair
  - St. Joseph
  - Sanilac
  - Schoolcraft
  - Sheawassee
  - Tuscola
  - Van Buren
  - Washtenaw
  - Wayne
  - Wexford
- Minnesota
  - Carlton
  - Cook
  - Lake
  - St. Louis
- New York
  - Allegany
  - Cattaraugus
  - Cayuga
  - Chautougua
  - Erie
  - Genesee
  - Hamilton
  - Herkimer
  - Jefferson
  - Lewis
  - Livingston
  - Madison
  - Monroe
  - Niagara
  - Oneida
  - Onondage
  - Ontario
  - Orleans
  - Oswego
  - St. Lawrence
  - Schuyler
  - Seneca
  - Tompkins
  - Waynge
  - Wyoming
  - Yates
- Ohio
  - Allen
  - Ashtabula
  - Auglaize
  - Crawford
  - Cuyahoga
  - Defiance
  - Erie
  - Fulton
  - Geauqa
  - Hancock
  - Hardin
  - Henry
  - Huron
  - Lake
  - Lorain
  - Lucas
  - Medina
  - Mercer
  - Ottawa
  - Paulding
  - Portage
  - Putnam
  - Sandusky
  - Seneca
  - Summet
  - Van Wert
  - Williams
  - Wood
- Pennsylvania
  - Erie
  - Crawford
- Wisconsin
  - Ashland
  - Bayfield
  - Brown
  - Calumet
  - Door
  - Douglas
  - Florence
  - Fonddu Lac
  - Forest
  - Iron
  - Kenosba
  - Kewaunee
  - Langlade
  - Monitawol
  - Marinette
  - Marquette
  - Milwaukee
  - Oconto
  - Outagamie
  - Ozaukee
  - Plaupaca
  - Portage
  - Racine
  - Shawane
  - Sheboygan
  - Vilas
  - Walworth
  - Washington
  - Waukesha
  - Waupach
  - Wanshara
  - Winnebago

Section 3

REVIEW OF FINDINGS OF PREVIOUS STUDIES

3.1 General Description of Land Use Category

This section addresses a somewhat unique land use category in that the land under consideration is undeveloped and has no major land use. This type of land use can be considered synonomous with the term "natural areas". Natural areas within the Great Lakes region can be subdivided into many ecological types (Table 1). However, many of these classifications account for for only a small percentage of the undeveloped land in the Great Lakes drainage basin. This report will deal with those classifications which may have a significant impact on water quality.

TABLE 1

CLASSIFICATION OF NATURAL AREAS IN THE GREAT LAKES REGION

I. Wetlands
    A. Submerged lands (stream and lake bottoms)
    B. Marshes
    C. Muskegs
    D. Swamps

II. Marginal Lands
    A. Bogs
    B. Beaches and dunes
    C. Flood plains
    D. Banks and bluffs (stream and lake)
    E. Lands periodically flooded by perched water bodies

III. Uplands
    A. Barren lands (rock, sand, and glacial till)
    B. Praries and grasslands
    C. Forests and woodlots
    D. Old fields and abandoned lands

Forest lands occupy 16,045,000 hectares (39,625,000 acres) (46 percent) of the surface area of the Great Lakes Basin, submerged lands under small lakes and streams (exclusive of the Great Lakes) account for another 1,185,000 hectares (2,927,000 acres) (3 percent), and all other natural areas total 1,965,000 hectares (4,853,000 acres) or 55 percent of the Basin. Table 2 presents a breakdown of these three types of undeveloped areas by the Great Lakes Basin Commission Planning Subareas. The boundaries of the planning subareas (22) are shown in Figure 1.

TABLE 2

UNDEVELOPED AREAS IN THE GREAT LAKES BASIN

Planning Subarea	Lake Basin	Area in 1,000 Acres (405 Hectares)				
		Forest Lands	Other Natural Areas	Rivers, Lakes and Embayments	Total Undeveloped	Total All Uses
1.1	Superior	8,355	305	851	9,511	10,325
1.2	Superior	5,910	66	232	6,208	6,674
2.1	Michigan	5,117	757	391	6,265	10,402
2.2	Michigan	341	580	104	1,025	5,316
2.3	Michigan	1,705	598	171	2,474	9,126
2.4	Michigan	5,434	412	345	6,191	8,439
3.1	Huron	2,914	219	149	3,282	4,167
3.2	Huron	1,194	285	37	1,516	4,461
4.1	Erie	666	222	82	970	4,062
4.2	Erie	453	349	49	851	6,369
4.3	Erie	539	288	24	851	2,332
4.4	Erie	1,365	109	43	1,517	3,113
5.1	Ontario	872	98	18	988	2,477
5.2	Ontario	2,546	428	255	3,229	5,683
5.3	Ontario	2,215	136	176	2,527	3,562
Basin Total	Great Lakes	39,625	4,853	2,927	47,405	86,507
Percent of Basin	Great Lakes	46.0%	6.0%	3.0%	55.0%	100.0%

Data Source: Benzmann and Kerr (4).

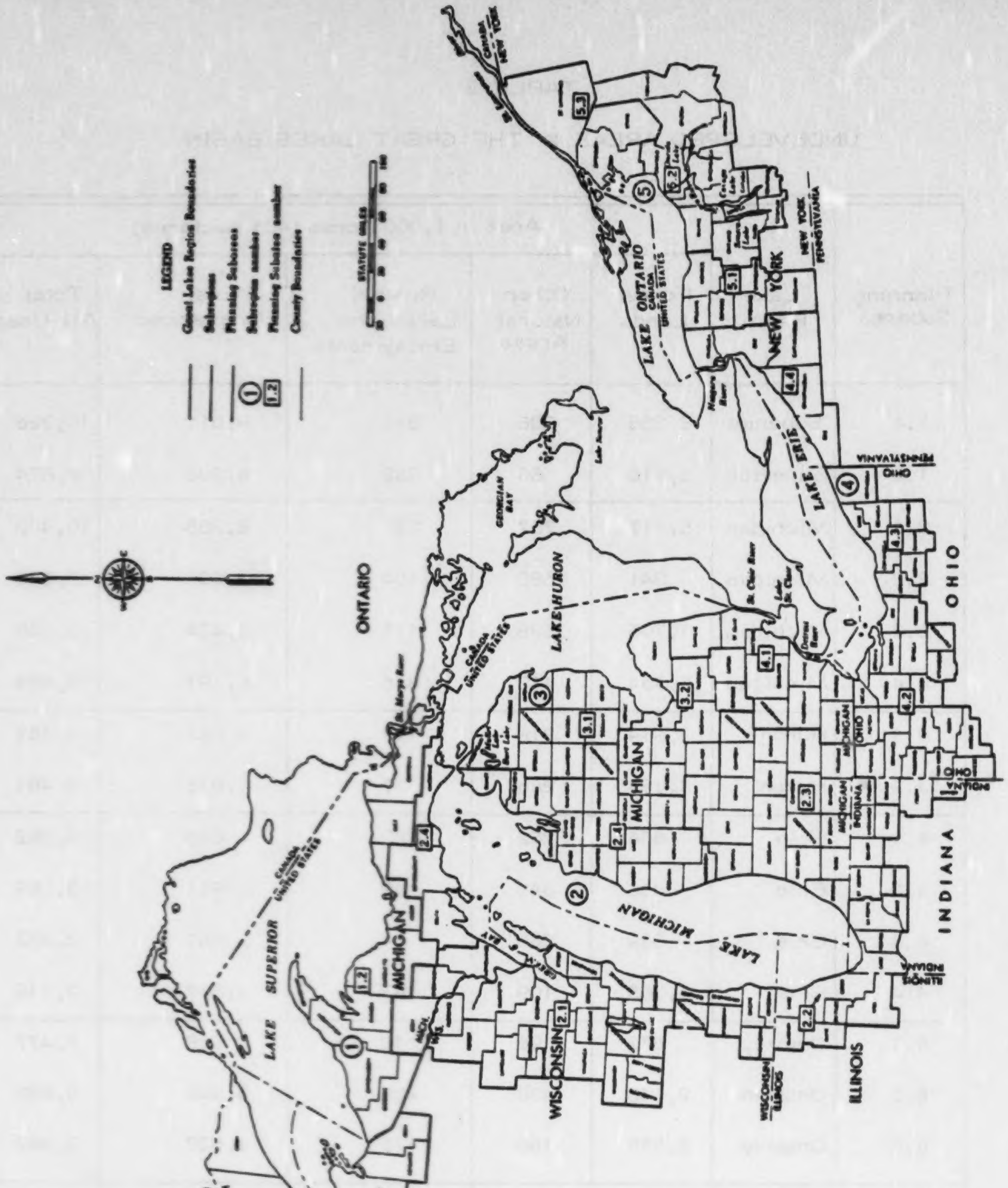

FIGURE 1

GREAT LAKES REGION

PLANNING SUBAREAS

GREAT LAKES BASIN COMMISSION

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Forest lands taken together represent 84 percent of the total natural or undeveloped area in the Great Lakes Basin. These forest areas can be divided in terms of whether deciduous (hardwoods) or conifers (softwoods) predominate. Hardwoods have broad leaves and retain them only in the warmer part of the year. The hardwoods are the major component (76 percent) of the Basin's forest land. Conifers have needle-like leaves and with a few exceptions are in leaf throughout the year. The softwoods represent only 24 percent of the forest land in the Basin (4).

Two hardwood forest regions exist in the Great Lakes Basin. They differ in species, growing conditions and hydrologic characteristics. The northern hardwood region occupies the most northerly and elevated portion of the Basin and makes up 70 percent of the hardwood forest. To the north and east it merges imperceptibly into the conifer forests as the growing season becomes shorter and plant growth is limited by temperature rather than moisture availability. To the south it merges into the eastern hardwood region as the growing season becomes longer, and as rising summer temperatures reduce the available supply of soil moisture during the growing season. The major forest types are the maple-beech-birch type and the aspen-birch type. The eastern hardwood region is 30 percent of the hardwood forests and covers a great range in growing conditions. In the north and at higher elevations in the east its range is limited by low temperatures. There is a great variety in the natural vegetation and a growing season that is long and well supplied with rainfall. A great number of tree species can be found in this region. In the high land of the region, the oak-hickory type is present. The elm-ash-cottonwood forest type is dominant in the lowland (4).

The softwoods are made up of two distinct forest types, the spruce-fir type and the white-red-jack pine type. There distinction has a hydrologic significance. The spruce-fir type makes up 64 percent of the conifer forests and is variable in composition, depending primarily upon soil drainage conditions. In poorly drained locations conifers occupy the soil almost completely, but on well-drained areas it can be found mixed with northern hardwoods. The over-all appearance of spruce-fir type is of dense growth, with large openings present only where swamp waters are deep or where large areas of bare rock are exposed. The climate in which it is found is humid and temperature rather than moisture availability limits plant growth. The pine type is scattered throughout the northern portions of the Basin. The species involved are white, red, and jack pine. The climate over their range is cool and humid. This type is usually most closely associated with well-drained sandy soils and usually possess single-storied crown and open spaces beneath (4).

Submerged lands under major streams and lakes greater than 40 acres account for 10 percent of the undeveloped areas of the Great Lakes Basin. The remaining 6 percent of the undeveloped land in the Basin consists of all the other types of natural areas listed in Table 2 plus a minor amount of land use such as farm roads, ditch banks, fence and hedge rows, and idle land (4).

Natural fish and wildlife wetlands and marshes are located on Lakes Michigan, Huron, Erie, Ontario, St. Clair and in the St. Marys River.

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However, the most extensive wetland areas are located along the west shore of Green Bay on Lake Michigan and in Saginaw Bay on Lake Huron and in Lake St. Clair. Other major wetland areas are located at the western end of Lake Erie and at the outlet of Lake Ontario to the St. Lawrence River. Lake Superior has the least amount of wetlands of any of the Great Lakes. Almost all of the wetlands in the Great Lakes are undiked. The only diked areas are located in Ohio. The State of Ohio pumps water in and out of these diked marshes to maintain a desirable water level for waterfowl (24).

3.2 Length of Time Activity in Practice

Undeveloped land or no activity is of course the oldest type and predates any other use of the land within the basin. The present landscape was formed as the last ice sheets of the Wisconsin glacier (Pleistocene Epoch) receded from the basin during the interval from 32,000 to 7,000 years ago. Due to crustal readjustment following deglaciation, the present water levels in the Great Lakes were not stabilized until about 4,000 years ago. Since that time soil zones have formed on the glacial till, many kettle lakes have passed through trophic stages to become bogs, and grasses and forests have undergone biological succession over most of the basin.

Some of the land area that has been lumbered, pastured or tilled during the past 200 years is no longer supporting these activities and has been allowed to return to undeveloped areas but still remains greatly altered from its natural state. The total acreage for such lands is not available but it is believed to be small for agricultural land but sizable for forested areas.

3.3 Types and Nature of Pollutants Associated with Land Use.

Because of the absence of any major use of the land under consideration in this section, impurities in the water drained from these areas can be considered as "natural pollutants." Natural waters, of course, are never pure. Turk, et al (51) have outlined the sources and nature of impurities found in natural waters (Table 3). All of the pollutants listed in Table 3 are contributed to the Great Lakes system from undeveloped land. The magnitude of this contribution has been determined for only a few parameters but is only vaguely known for others.

Chemical loading to the Great Lakes is a result of the interaction of natural weathering and cultural wastes. Natural weathering yields loads of constituents that reflect the lithology of the source terrane. Streams that drain areas of igneous and metamorphic bedrock (Figure 2) are generally subjected to lower chemical loads than streams from shale and limestone-dolomite terranes because weathering rates of silicate minerals are slower than those of calcite and dolomite. Streams that drain areas of glacial materials (Figure 3) are also high in chemical loads because of the unconsolidated nature and small particle sizes of the sediment (54). Natural or predevelopment rates have been estimated from historical data from Beeton(2).

TABLE 3

IMPURITIES IN NATURAL WATER

Source	Particle Size Classification				
	Suspended	Colloidal	Dissolved		
			Molecules	*Positive ions*	*Negative ions*
Atmosphere	←Dusts→		Carbon dioxide, CO_2 Sulfur dioxide, SO_2 Oxygen, O_2 Nitrogen, N_2	Hydrogen, H^+	Bicarbonate, HCO_3^- Sulfate, SO_4^{2-}
Mineral soil and rock	←Sand→ ←Clays→ ←Mineral soil particles→		Carbon dioxide, CO_2	Sodium, Na^+ Potassium, K^+ Calcium, Ca^{2+} Magnesium, Mg^{2+} Iron, Fe^{2+} Manganese, Mn^{2+}	Chloride, Cl^- Fluoride, F^- Sulfate, SO_4^{2-} Carbonate, CO_3^{2-} Bicarbonate, HCO_3^- Nitrate, NO_3^- Various phosphates
Living organisms and their decomposition products	Algae Diatoms Bacteria ←Organic soil (topsoil)→ Fish and other organisms	Viruses Organic coloring matter	Carbon dioxide, CO_2 Oxygen, O_2 Nitrogen, N_2 Hydrogen sulfide, H_2S Methane, CH_4 Various organic wastes, some of which produce odor and color	Hydrogen, H^+ Sodium, Na^+ Ammonium, NH_4^+	Chloride, Cl^- Bicarbonate, HCO_3^- Nitrate, NO_3^-

Data source: Turk, et al (51).

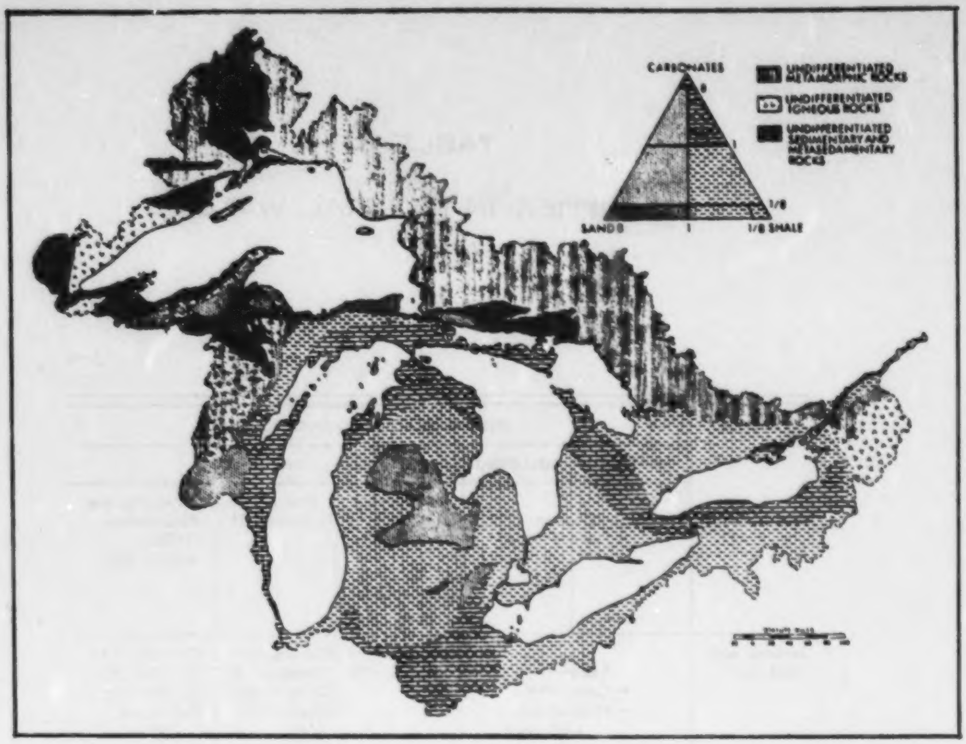
CARBONATES
8
1
1/8
SANDS
1
1/8 SHALE
UNDIFFERENTIATED METAMORPHIC ROCKS
UNDIFFERENTIATED IGNEOUS ROCKS
UNDIFFERENTIATED SEDIMENTARY AND METASEDIMENTARY ROCKS

FIGURE 2. Composition of rock exposed at the pre-Pleistocene erosional surface (Upchurch, 54).

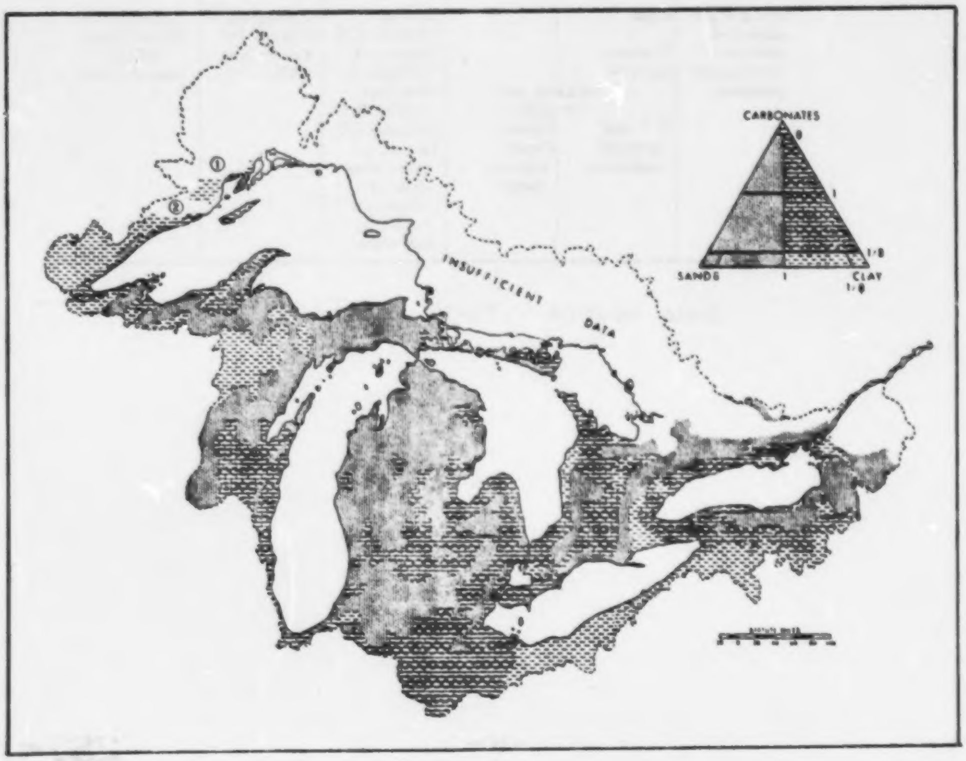

FIGURE 3. Composition of Pleistocene and Recent surficial sediments (Upchurch, 54).

Upchurch (54) considers the earliest chemical records as representing steady state concentrations for the Great Lakes before the recent, rapid rise in population, urbanization and industrialization when weathering on drainage basins with only lumbered, sparse agricultural and forested area was producing the only loadings to the lakes. This assumption is based on the fact that chemical concentrations in Lake Superior have remained essentially unchanged in the past 100 years which indicated that load of a natural origin reach a steady state concentration in that inflow of a particular constituent equals outflow plus biotic and sediment uptake and that there is no change in composition of the lake (Upchurch and Robb, 55). Table 4 shows the annual natural loads and rates of weathering of several chemical parameters for each lake drainage basin derived from these early records. Lake Superior shows the lowest rate reflecting the poor drainage and slow weathering characteristic of the Canadian Shield, and Lake Erie yields the highest rate because of the early human utilization of the basin and the extensive carbonate terrain. These rates are in general agreement with estimates by Durum, et al (13) of 1 x 10^4 (5.7 x 10^4lbs/mi^2/yr) to 4 x 10^4 kg/ km^2/yr (22.8 lbs/mi^2/yr) for gross yields of dissolved solids for several drainage basins in eastern United States due to natural weathering. Upchurch (54) points out that rather high weathering should be expected from recently glaciated terrain owing to the relatively high chemical reactivity of the fine grain-sized sediment produced by the glaciation process.

The modern chemical loads to the Great Lakes from natural and cultural activity is shown in Table 5. Upchurch (54) concludes that Lakes Superior and Huron show the least changes in loading and weathering rates with natural loads still accounting for 87 percent. Lakes Michigan, Erie and Ontario receive significant cultural loads with the natural load resulting in only 63, 47, and 38 percent of the total, respectively.

Stream bank and lake shoreline erosion contributes approximately 10 percent of sediment delivered to the Great Lakes (4 and 14). Table 6 shows the tonage delivered to each of the Great Lakes. Siltation of the Great Lakes from these sources is a local problem in harbors where it causes severe discoloration and a need for frequent dredging. To a lesser extent siltation tends to periodically cover coarser sediments and rock which are spawning areas for fish and other aquatic life. One of the principal concerns regarding the silt load to the lakes is the amount of nutrients and other chemicals contained within the silt (16).

Another form of natural pollutants is biological wastes and debris such as leaves, fallen trees, stumps and other detritus. This material chokes streams at many places, blocking flow and collecting floating material. During high flows the debris is flushed downstream to harbor areas and to the lakes where it interfers with commercial navigation and recreational boating (16).

Lake Superior is by far the least polluted of the Great Lakes. Because of its relatively pure nature, natural pollutants are more readily recognized and are not masked by cultural wastes. Three specific natural inputs have been identified. Water quality of the Ontonagon River Basin (Michigan and Wisconsin) is generally excellent except for a natural silt load attributed to the clay lands of the basin (25). The Tahquamenon River which discharges

TABLE 4

NATURAL CHEMICAL LOADS AND BASIN WEATHERING RATES FOR GREAT LAKES DURING THE PERIOD 1870-1910

Parameter	Superior		Michigan		Huron		Erie		Ontario	
	Load[1]	W Rate[2]	Load	W Rate	Load	W Rate	Load	W Rate	Load	W Rate
Total Dissolved Solids	39.0	3.1	61.0	5.2	-	6.0	80.0	10.0	40.0	6.3
Chloride (Cl^{-1})	1.9	0.19	2.2	0.19	4.0	0.30	1.2	0.15	-	-
Calcium (Ca^{+})	7.9	0.63	15.0	1.30	16.0	1.20	17.0	2.30	8.0	1.30
Sulfate (SO_4^{-2})	2.3	0.18	3.8	0.32	4.9	0.37	13.0	1.70	6.0	0.95
Sodium (Na^{+}) and Potassium (K^{+})	2.1	0.17	1.4	0.12	3.3	0.25	5.2	0.68	2.0	0.32

Data Sources: Beeton (3) and Upchurch (54).

[1] loads in 10^8 kg/yr (2.2×10^8 lb/yr)

[2] W rates in 10^4 kg/km^2/yr (5.7×10^4 lb/mi^2/yr)

TABLE 5

MODERN NATURAL AND CULTURAL CHEMICAL LOADS TO THE GREAT LAKES

Lake	Total Dissolved Solids					
	Natural		Cultural		Total	W Rate
	10^8 kg/yr[1]	% total	10^8 kg/yr[1]	% total	10^8 kg/yr[1]	10^4 kg/km^2/yr[2]
Superior	39	87%	6	13%	45	3.6
Michigan	61	63%	36	37%	97	8.2
Huron	Insufficient Data				58	4.3
Erie	80	47%	90	53%	170	22
Ontario	40	38%	67	62%	107	18

Data Source: Upchurch (54).

[1] 10^8 kg/yr = 2.2×10^8 lb/yr

[2] 10^4 kg/km^2/yr = 5.7×10^4 lb/mi^2/yr

TABLE 6

SEDIMENT DELIVERED TO THE GREAT LAKES

Lake	Erosion in Tons/Year (0.91MT/Year)				
	Sheet	Streambank	Shoreline	Urban and Roadside	Total
Superior	117,600	29,400		37,000	
Michigan	1,929,000	61,000		53,000	
Huron	Data not available.				
Erie	2,610,300	36,800	16,000	127,000	2,790,100
Ontario	Data not available.				
Total					

Data Sources: Benzmann and Kerr (4), Federal Water Pollution Control Agency (16), and U. S. Army Corps of Engineers (53).

into Whitefish Bay is noted for its unusual color. The surface waters are colored because of tannins naturally present in the basin (25). The tannins are produced in acid bogs and muskegs which are abundant in the region. The shoreline at the western end of the lake and the interior drainage basins contain an easily erodible red clay which discolors the streams and lake (29). Several trout streams have been destroyed by sedimentation of the material (37).

Bormann and Likens (6) studied nutrient cycles in a natural deciduous forest ecosystem in New Hampshire and found net losses for most elements. They found the average annual budget for the following elements:

	Input		Release	
	kg/km^2	lb/mi^2	kg/km^2	lb/mi^2
Calcium	260	1653	1180	6726
Sodium	150	855	690	3933
Magnesium	70	399	290	1653
Potassium	110	627	170	969

The generalized calcium cycle for an undisturbed beech-maple forest ecosystem is shown on Figure 4.

A 15.6 hectare (39.0 Acres) segment of the forest was deforested in 1956 and nutrient inputs and releases were monitored at the test area and in undisturbed portions of the forest. The experiment demonstrated that net losses of potassium were 21 times higher in the test plot than in the undisturbed watershed; calcium 10X; aluminum 9X; magnesium 7X; and sodium 3X.

The releases of chemicals from the undisturbed forest lands are considerably lower than (2 to 5X) the natural weathering rate for Lake Superior calculated by Upchurch (54). However, release rates for the deforested areas are twice as high as the natural rate for Lake Superior, but compare well with the natural rate for the lower lakes.

Fisher and Likens (18) studied the natural organic energy budget of a stream ecosystem in a deciduous forest in New Hampshire. They found that energy entered the stream by a variety of pathways. Meteorologic inputs consist of litter (leaves, branches, twigs, etc.) which fall or are blown into the stream in through-fall (precipitation which has passed through the forest canopy). Geologic fluxes consist of groundwater inputs and dissolved and particulate matter imported or exported in stream water. Biological input consists of in situ primary production. Respiratory heat lost is a biological output. Meteorological, geologic and biological vectors accounted for 44.2, 45.5 and 10.3 percent of total energy input, respectively. Energy lost by stream flow to downstream areas was 66 percent of the output. The remaining 34 percent represented respiratory loss, mostly by microorganisms. Similar values can probably be assumed for hardwood forests of the Great Lakes Basin.

12.3.4 State-of-the-Art in Assessing and Quantifying Problem

Models for assessing the contribution of various lithologic components

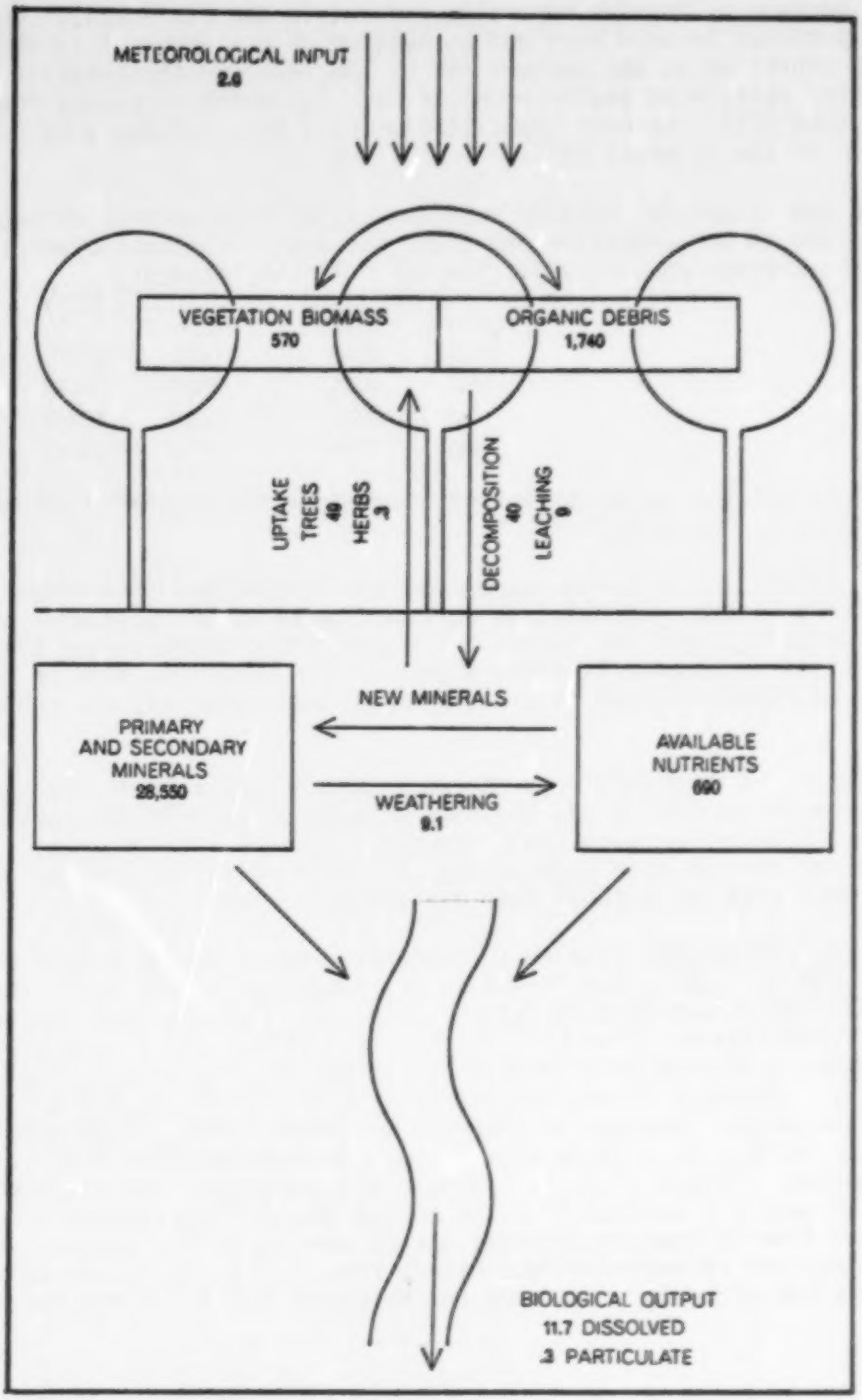

FIGURE 4. Calcium cycle for a forest ecosystem. Numerals represent the average number of kilograms per hectare per year; developed by Bormann and Likens (5). (1 kilogram per hectare per year equals 0.89 pounds per acre per year).

to the chemical loads of the Great Lakes through natural weathering have been developed by Upchurch (54) and Upchurch and Robb (55). These models assume steady state concentrations of chemicals in the lakes prior to human activity.

Several studies have been conducted in deciduous forests in New Hampshire (5, 6 and 18) which model nutrient inputs and outputs in that type of ecosystem. The models developed for New Hampshire can probably be applied to similar areas in the Great Lakes Basin.

Investigations by the U.S. Army Corps of Engineers (53) provide methods of assessing and quantifying shore erosion problems along the Great Lakes. These techniques were developed to show material losses from beaches and bluffs and do not specifically relate to chemical inputs.

Agricultural experiment stations in all of the Great Lakes states are conducting research on nutrient enrichment of waters. Some are including the contribution of soil erosion and water runoff and the role of sediment-nitrogen and sediment-phosphorus interactions in eutrophication (14).

12.3.5 Mobility of Pollutants and Natural Renovation Mechanisms

The materials which fall into the category of natural pollutants are many and varied. They include such substances as (a) dissolved chemicals leached from soil and rock, (b) suspended sediment and other particles, (c) leaves, branches and other plant materials and (d) wild animal wastes. Because of this wide variety, the mobility will also be divergent. Leaching rates for each lake basin are given in Table 4 and sediment delivery rates are presented in Table 6. Plant debris and animal wastes are more difficult to quantify. Fisher and Likens (18) believe that streams draining intact forested watersheds are highly heterotrophic, receiving a major portion of their energy from the surrounding forest. The forest transforms solar energy to carbon compounds which enter the stream as detritus and dissolved organic matter. The latter accounted for 47 percent of the total energy input in their study area.

The principal natural renovation mechanisms are related to the cycling of materials in an ecosystem. The principal producer organisms of stream ecosystems are the attached algae, plankton algae, rooted aquatic plants, and such terrestrial plants whose parts may fall or become washed into the stream. The annual leaf fall in some deciduous forest areas make a major contribution. The submergent aquatic producers must depend largely upon those raw materials (O_2, CO_2 dissolved mineral salts, etc.) either present in the stream proper or available from the substrate. The emergent and terrestrial vegetation also have the atmosphere as a raw material resource.

The transformation from a stream system to a lake changes a number of physical factors which will be reflected in the entire system. A part of this impact will be direct and part by way of changes in trophic dependencies. It is relatively certain that the rooted or otherwise attached plants in and adjacent to a stream are its major producers. A flowing stream has planktonic life to the extent that the pool areas between the riffle-run features resemble lakes. In the Great Lakes, the planktonic algae are the principal producers. To complete the cycle, an important group of organisms occupying the niche of decomposers (bacteria, yeast and fungi) perform the task of breaking down dead organisms and their waste products into simpler substances that can be reused by the producers (green plants).

3.6 Probable Changes in Land Use and Projected Pollution

Benzmann and Kerr (4) have projected the use of forest and other natural areas for the years 1980, 2000 and 2020. They predict that forest acreage will decrease by only 3 percent in 46 years and that other natural areas will diminish by 10 percent (Table 7). Because natural areas are normally at equilibrium and have been for some time, it is unlikely pollution loads will increase from these areas or change in constituents. Considering the projected decrease in the area of this land use category, as a result of forest loss and shoreline developments future pollution loads will likewise be less.

3.7 Review of Institutional Arrangements to Regulate Land Use

The regulation of federally owned undeveloped land is normally assumed by the managing agency. Most of the federal lands in this category within the Great Lakes Basin are administered by the U.S. Forest Service of the Department of Agriculture. Some wetlands areas are designated as wildlife sanctuaries and are administered by the U.S. Fish and Wildlife Service of the Department of the Interior.

State-owned natural areas are usually managed by natural resources and conservation departments. Other undeveloped public lands are owned by universities, conservation districts, museums, park districts, municipalities and similar groups.

Considerable undeveloped acreage is also owned by private corporations or individuals. These include investment tracts, hunting associations, abandoned farm and timber lands, etc.

Because of the non-use nature of this category and the lack of significant pollution loadings, regulations have not been imposed upon discharges from these lands. Most states have some form of legislation designed to preserve such lands or to provide incentives to encourage private owners to restrict development on natural areas.

TABLE 7

PROJECTED UNDEVELOPED LAND USE IN THE GREAT LAKES BASIN

Planning Subarea	Lake Basin	Area in 1,000 Acres (405 Hectares)							
		1967		1980		2000		2020	
		Forest Areas	Other Natural Areas	Forest Areas	Other Natural Areas	Forest Areas	Other Natural Areas	Forest Areas	Other Natural Areas
1.1	Superior	8,355	305	8,354	305	8,347	304	8,334	304
1.2	Superior	5,910	66	5,910	66	5,909	66	5,906	66
2.1	Michigan	5,117	757	5,104	755	5,081	752	5,052	748
2.2	Michigan	341	580	297	505	240	408	197	335
2.3	Michigan	1,705	598	1,683	590	1,649	579	1,608	564
2.4	Michigan	5,434	412	5,424	411	5,403	410	5,380	408
3.1	Huron	2,914	219	2,908	219	2,900	218	2,889	217
3.2	Huron	1,194	285	1,179	281	1,156	276	1,141	270

TABLE 7 (Con't).

Planning Subarea	Lake Basin	Area in 1,000 Acres (405 Hectares)							
		1967		1980		2000		2020	
		Forest Areas	Other Natural Areas	Forest Areas	Other Natural Areas	Forest Areas	Other Natural Areas	Forest Areas	Other Natural Areas
4.1	Erie	666	222	605	222	519	173	462	154
4.2	Erie	453	349	449	346	441	339	432	333
4.3	Erie	539	288	494	264	411	220	343	183
4.4	Erie	1,365	109	1,337	107	1,288	103	1,243	99
5.1	Ontario	872	98	860	97	843	95	823	93
5.2	Ontario	2,546	428	2,510	422	2,465	415	2,417	407
5.3	Ontario	2,215	136	2,215	136	2,210	136	2,205	135
Basin Total	Great Lakes	39,625	4,853	39,327	4,706	38,863	4,493	38,430	4,317
Percent of 1967 Area	Great Lakes	100.0%	100.0%	99.7%	95.6%	98.1%	93.5%	97.0%	90.0%

Data Source: Benzmann and Kerr (4).

Section 4

SUMMARY OF ONGOING OR PROPOSED RESEARCH, DEMONSTRATION, OR MONITORING PROGRAMS

4.1 Nature of Studies and Relevancy

Owing to the fact that natural pollution is not a major contributor to the degradation of stream and lake water quality (other than the long-term natural eutrophication process) and the realization that these kinds of impurities would be difficult to control, there has been only a limited amount of research on this topic. The present inventory has uncovered only a few investigations that are presently ongoing or proposed. These are summarized below:

1. Project Topic: Natural Weatering and Chemical Load in the Great Lakes
2. Investigator(s): Dr. Sam B. Upchurch and Associates
3. Institution or Agency: Michigan State University, Department of Geology and Lake Survey Center, NOAA
4. Period of Program: 1968-present
5. Objectives: To determine the natural and cultural chemical loads to each of the Great Lakes and develop mathematical models.
6. Relevancy: Study will yeild an estimate of steady state inputs prior to habitization of the Basin.

1. Project Topic: The Nutrient Cycles of a Forest and Stream Ecosystem
2. Investigator(s): Gene E. Likens and Associates
3. Institution or Agency: Cornell University, Ithica, New York
4. Period of Program: 1970-present
5. Objectives: To determine how a natural ecosystem works, what the inputs and outputs are and how they occur.
6. Relevancy: The study will provide data on the effect of a forested watershed on the stream.

1. Project Topic: Shoreline Studies of Great Lakes States
2. Investigator(s): North Central Division, U.S. Army Corps of Engineers
3. Institution or Agency: U.S. Army Corps of Engineers
4. Period of Program: 1877-present
5. Objectives: To study shoreline erosion and land use.
6. Relevancy: This study indicates shore uses and shoreline erosion rates.

1. Project Topic: Shore Erosion on the Southern Shore of Lake Erie
2. Investigator(s): Charles Carter and Associates
3. Institution or Agency: Ohio Geological Survey
4. Period of Program: 1953-present
5. Objectives: To study shore erosion along the Ohio shoreline of Lake Erie.
6. Relevancy: This study provides data concerning bedrock geology and erosion rates.

1. Project Topic: Red Clay Soils of Northwestern Wisconsin and Lake Superior Shoreline
2. Investigator(s): Interagency Red Clay Committee
3. Institution or Agency: Wisconsin Soil Conservation Board
4. Period of Program: 1958-present
5. Objectives: To study land use problems on the red clay soils of northwestern Wisconsin and to determine the cause of extreme sedimentation in lakes and streams.
6. Relevancy: Study provides data on natural pollution from the red clay soils.

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1. Project Topic: Water Resource Planning in the Great Lakes Region
2. Investigator(s): Forest Service Scientists
3. Institution or Agency: U.S. Forest Service
4. Period of Program: Continuing
5. Objectives: To determine objectives and needs for those land areas and waters influenced by the National Forests
6. Relevancy: Information concerning quantity, timing, and quality of flows and lakes is available.

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1. Project Topic: Water Resource Management in the Great Lakes Region
2. Investigator(s): National Forest Service Scientists
3. Institution or Agency: U.S. Forest Service
4. Period of Program: Continuing
5. Objectives: To evaluate the influence of various land management practices of the Forest Service upon the quality of the water resources of the seven National Forests within the Great Lakes Basin.
6. Relevancy: Provides information concerning the quality of water entering the Great Lakes from the forested watershed.

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1. Project Topic: Abatement, Prevention and Control of Water Quality Problems in the Great Lakes Basin
2. Investigator(s): Environmental Protection Agency
3. Institution or Agency: Environmental Protection Agency
4. Period of Program: Continuing
5. Objectives: To abate, prevent, and control all water quality problems.
6. Relevancy: Provides information on water quality problems in the Great Lakes Basin.

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1. Project Topic: Nutrient enrichment of Great Lakes Waters
2. Investigator(s): Agricultural Experimental Stations
3. Institution or Agency: U.S. Dept. of Agriculture
4. Period of Program: Continuing
5. Objectives: To determine the contribution of soil erosion and water runoff and the role of sediment-nitrogen and sediment-phosphorus interactions in eutrophication
6. Relevancy: Provides information on various nutrient inputs to the Great Lakes.

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Section 5

NATURE AND AVAILABILITY OF TECHNOLOGY TO COPE WITH POLLUTION PROBLEMS

The technology available concerning natural pollution is very limited. Although the problem has exsisted since the geologic formation of the area, man's interest has only recently been aroused.

Upchurch (54) used the formula: natural load=weathering+precipitation when working with levels of natural pollution in the Great Lakes Basin. The formula appears to be an effective tool but only continued testing will be an accurate evaluation of its effectiveness.

Hilty and Kinkle (27) determined the outflow components from natural areas by studying the hydrography of the area. They were then able to express this in a flow diagram. This system was developed for work in the Great Lakes Basin and provides the sources and quantities of the pollutants.

The U.S. Forest Service (21) has developed a method to relate silviculture practices to the quality of the water leaving the forests in the Great Lakes Basin. The method is new and needs to be evaluated.

The Red Clay Interagency Committee (37) has developed a number of techniques that can and are being used in Wisconsin to prevent the natural pollution of Lake Superior from the red clay banks. Among these techniques are seeding, mulching and bank stabilization. These methods hold promise for the control of the Wisconsin red clay problem.

Likens and associates (6, 12, 5) developed techniques for determining the ecological relationship between a forested watershed and the streams draining it. The study in which the techniques were used was done by the Hubburd Brook Experimental Forest Station, New Hampshire. Meteorological inputs were measured by a network of gauging stations. Geologic outputs were measured by means of a weir built at the foot of each watershed. Using the weir, which also contained a ponding basin, the water leaving the watershed could be measured and, by combining these data with frequent chemical measurements the quantities of chemical substances that are leaving the watershed could be ascertained. This study could provide valuable data indicating how proper management could reduce material pollution levels.

Section 6

NEED FOR NEW RESEARCH, DEMONSTRATION OR MONITORING PROGRAMS

The study of natural pollution is a relatively new field, though the problem and processes have been occuring throughout man's exsistence. There are many important questions that need to be answered. A good starting point would be to define, or determine what the natural pollution problem is. This should then be followed by an evaluation program to determine the causes and extent of the problem. A third and final phase of the research effort should deal with two questions: a) can the natural pollution problem be controlled and b) does it need to be controlled.

There is also a need for studies to develop techniques to determine and measure the inputs and outputs of various natural land uses in the many watersheds of the Great Lakes Basin. The continuing projects dealing with natural pollution may provide these answers and techniques. New studies with these goals in mind could greatly speed up the knowledge acquisition process.

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Section 7

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Section 8

GLOSSARY

1.	Barrens	A tract of natural land consisting mainly of rock, sand or glacial till which will not support vegetation due to the lack of a soil zone or absence of moisture. Oak and Pine Barrens are tracts containing predominately these types of trees which are widely spaced with a lack of understory plants.
2.	Beach	The gently sloping shore of a body of water which is washed by waves, generally composed of sand or gravel and a lack of vegetation.
3.	Bog	An area of soft, wet spongy ground consisting chiefly of decayed or decaying moss and other vegetable matter. It often forms in shallow, stagnant lakes or ponds, and is largely produced by sphagnum moss, from which eventually peat is evolved. Bogs may also be formed on cold, damp moutain surfaces.
4.	Dune	Ridge or mound of loose, wind-blown material, usually sand.
5.	Flood plain	The lowland that borders a river, usually dry but subject to flooding when the stream overflows its banks.
6.	Marsh	A tract of soft, wet land, usually low-lying and partly or completely under water; the extreme dampness is due to the impermeable nature of the soil (such as clay) and the poor drainage.
7.	Muskeg	The water portion of a moss peat bog; characterized by a strong acid reaction, an absence of oxygen and carbonates and a low specific conductance.
8.	Natural area	A tract of land or waterway which is undisturbed by human activity.
9.	Natural pollution	Soil, mineral or bidogical impurities picked up by water from the earth's surface, apart from any human activity.
10.	Perched water body	A suspended, isolated body of groundwater occurring in a saturated zone, separated from the main body of groundwater by unsaturated, impermeable rock. The isolated body has its own local water table (perched water table).
11.	Prairie	A tract of broad, flat land with chief vegetation being grasses; often treeless.

12.	Swamp	A tract of low-lying land that is saturated with moisture and usually overgrown with vegetation. A marsh, unlike a swamp, is ordinarily covered with water; a bog, unlike a swamp, consists largely of decaying vegetation. The dampness of a swamp is due to some obstruction to normal drainage, because of the flatness of the land, the presence of impermeable rocks, or the growth of vegetation. A swamp is often formed in a lake basin as it fills up; because the surface is flat the rain water runs off very slowly, and the growth of vegetation in the damp soil helps maintain the swampy condition.
13.	Undeveloped land	A tract of land that has not been altered for human purposes; also formerly developed land that has been abandoned and allowed to return or proceed toward a natural state.
14.	Wetlands	Lowlands which are covered with shallow water most of the time; subject to temporary uncovering during dry periods.

Land Use/Water Quality Relationships in the U. S. Great Lakes Basin
Task A: To assess problems, management of programs and research...
Category A13 - Liquid Waste Disposal

LIQUID WASTE DISPOSAL AREAS

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Section 1

SUMMARY

1.1 Introduction

This report is a State-of-the-Art document concerning the existing or potential pollution of the Great Lakes Basin associated with liquid waste disposal on land. Current public and professional interest in land application of wastes is high and has resulted in numerous current publication on the subject. This information greatly facilitated the development of this report.

Major consideration was given to land application of waste materials from municipal wastewater effluents and liquid sewage sludges, industrial effluents and sludges, and wastewaters from individual home waste treatment systems. The potential pollutants most often considered in land application systems are organic compounds, the biostimulants nitrogen and phosphorus, toxic organic compounds, heavy metal ions, a number of non-metallic inorganic elements and ions, and pathogenic microorganisms.

Application of wastewaters and liquid sludges, both industrial and municipal, to soils in the humid high rainfall area of the Great Lakes Basin has not been as common as in states of Western United States. Considerable evidence suggests that the use of land for waste treatment and renovation may become more popular in the Great Lakes Basin in the future. The continual construction of homes away from municipal sewage systems has and still makes septic systems and soil leach beds continually important throughout the Great Lakes Basin.

1.2. Summary and Conclusions

Information adequate to evaluate the existing pollution impact associated with the application of municipal and industrial wastes to soils for treatment or disposal are presently not available. All of the states within the Great Lakes Basin have a history of minimal control and concern with the operation of land treatment sites. At the present time, however, there is considerable state agency activity which is providing improved control, guidlines for design and operation, and in some instances supervised monitoring of land treatment facilities. These activities should result in the collection of appreciable data on the pollution potential of land treatment operations. Pollution problems associated with the myriad of individual home waste treatments systems are considered to be common place and locally severe. At this time no concerted effort has been made to quantify their impact on water quality within the Great Lakes Basin.

It is presently impossible to accurately predict the future trend in the use of land for treatment and renovation of liquid wastes. There are significant considerations both positive and negative which will influence the future acceptance of the land treatment alternative. The primary weight of evidence, however, suggests to this author a phenominal growth in the use of land treatment for municipal and industrial wastes

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in the near future. Conversely the use of land disposal and leach beds for sewage wastes from individual homes may be expected to decrease in the near future. In this case the combined impact of legislative controls, obvious community problems, and education may result in the realization. that many soils are unsuitable for treatment of septic tank effluents. The results will be combined sewage systems or the development of alternate systems of waste treatment.

The future environmental impact of land treatment systems for municipal and industrial wastewaters will probably be positive. The data presently available indicates that a properly designed and managed land treatment system for wastewater effluents has the potential for nearly complete removal of BOD and COD materials; pathogenic bacteria and viruses; phosphorus; detergent residues; and heavy metals. High levels of treatment are provided for nitrogen, sulfates, and chlorinated hydrocarbons. Various soluble salts such as boron, sodium, chloride, and calcium which together are measured as total dissolved solids (TDS) are not removed as affectively and may pose the greatest threat to water quality. Liquid sludges present some of the same environmental concerns as effluents. However, as with effluents, a properly designed and managed land system for sludges should not present an environmental hazard. Most significantly it must be remembered that soils are not disposal areas for sludges, but must be managed to assure renovation and recycling of sludge components.

It is not possible to be as optimistic about the future environmental impact of effluents derived from individual home treatment systems. Although the pollution hazard from such land treatment systems has been recognized few areas have been able to exert the needed leadership or legal power to prevent a continuation of the problem.

There is presently available a considerable quantity of research and experience which is useful in designing and managing effective land systems for treatment of most municipal and industrial wastes, both effluents and sludges. Considerable effort has been recently expended to delineate what further research is needed to provide even more effective treatment. Areas of research with high priority include improved techniques for measuring hydraulic conductivity, rate of mineralization rates of sludge nitrogen, rate of mineralization rates of sludge nitrogen, rate and magnitude of biological denitrification, improved methods of detecting virus in soils and waste waters, studies on the movement and mechanisms for pathogen survival in soils, and studies on the biological and chemical reactions which influence the solubility, mobility and plant uptake of heavy metals. Designers of individual home sewage systems have a need for improved technology for evaluating soil capabilities for soil adsorption systems, and alternative methods for small scale waste disposal which do not overload soil systems.

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Section 2

SUPPORTING MATERIAL

2.1 Introduction

The application of liquid wastes to land for the purpose of disposal is not a new concept (see brief historical review in Section 3.2). Numerical information on the overall impact of this land use area is difficult to obtain. State by state inventories of land treatment facilities have been difficult to complile. Many states have been until very recently largely uninvolved with the operation of land treatment (or disposal sites) and have not provided legal control or guidelines pertaining to their operation. Much of the information available on municipal land treatment and disposal systems has been reviewed by Thomas (1973). One report published in 1972 lists 571 municipalities serving a population of 6.6 million using land application for wastewaters. Another survey conducted in 1965 reports a much larger number, 947 cities, utilizing land for wastewater application. The thirteen western states by and large contain the major portion of these operations. The data in Table 1 is a compilation of all confirmed land disposal and treatment facilities for wastewater within states of the Great Lakes Basin as of 1972. Even though acknowledging that this list is already incomplete, it is apparent that the population served by land treatment systems represents a negligible portion of the total population in the basin.

Any consideration of liquid waste application to land must consider septic tank systems. Thomas (1973) has stated that more wastewater is applied to soils by this method than by any other approach (up to several billion gallons per day in the U.S.). The USDA Economic Research Service (1968) estimated that some 14 million homes, accounting for about 25 percent of the total U.S. population have septic tanks or cesspools for wastewater disposal. Extrapolating this percentage to the population of the basin (~32 million) would mean that approximately eight million people use septic systems at this time. There are no figures on the magnitude of pollution associated with these systems, but it could be locally severe. Winneberger (1972) estimates that approximately one-third of these septic tank systems will fail within three years of installation.

Land disposal of industrial wastewater ranks second in volume of wastewater applied to land although there is no readily accessible information to verify this ranking (Thomas, 1973). In 1965, approximately 1300 industrial facilities applied wastewater to land. Food processing industries are the dominant users of land disposal and treatment, with dairy and meat packing industries making up a large percentage of the remainder. Confirmed industrial users of land disposal of wastewater within the states of the Great Lakes basin are shown in Table 2. These data support the previous statement that the volume of industrial wastewater applied to land is second only to that of septic systems.

The previous data does not contain information on liquid sludge disposal sites in the Great Lakes Basin. Complete information is presently not readily available for states in the basin. An inquiry in the State of Ohio (Robert Brown, Ohio EPA, personal communication) suggests that municipalities disposing of sewage sludges on land may be more extensive than previously realized, particularly among smaller communities.

The previous brief reviews have demonstrated that land application of wastes is already an accepted alternative for treating and disposing of home, municipal and industrial wastes. Yet, at the present time we are in the midst of an amazing rekindling of interest in the land application mode of waste treatment. A listing of the major references dealing with this subject (see Section 7.1) emphasizes both the extensive and current interest in applying liquid wastes to land. The current attractiveness of the land treatment alternatives is probably associated with one or more of the following reasons; 1) It replaces direct discharge of treated wastewaters to streams, 2) is often cost effective in comparison to other methods of wastewater treatment on sludge disposal, 3) is encouraged somewhat by the wording of recent water pollution control legislation, 4) is environmentally attractive as a system of "recycling a resource out of place", and 5) may supplement potentially short supplies of fertilizer nutrients, especially phosphorus and nitrogen.

There can be little doubt that the use of land for application of liquid wastes within the Great Lakes Basin will increase substantially in the future. However, because the renewed interest in land use has resulted in a more scientific approach to design and management than ever before, the overall impact on ground and surface water quality within the Great Lakes Basin, should be favorable. The old idea of land disposal systems for wastes has apparently given way to the idea of land treatment systems for wastes.

2.2 Scope of Study

This report has considered pertinent data on land application of liquid wastes from a large number of published journal articles, abstracts, research reports, monographs, engineering studies, symposia, and guideline reports. These materials were not restricted only to studies within the Great Lakes Basin, but encompassed applicable data from numerous foreign countries and all geographical areas of the United States.

No attempt was made to limit the time frame under consideration for this study. It is perhaps fortuitous that the recent renewed interest in land application of municipal effluents and sludges as well as liquid industrial wastes has resulted in the publication of numerous symposia,

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proceedings workshop reports, study committee reports, engineering feasibility studies etc. that are both current and pertinent to this report.

2.3 Study Procedure

The content of this report represents the author's best attempts at interpreting and synthesizing all published information on liquid waste disposal as this information applies to Task A, Land Use/Water Quality Relationships. For a detailed listing of all published information reviewed for this report see Section 7. In addition, the author's current research activities and participation in symposia, workshops, study committees, etc. have brought them in frequent contact with individuals and groups concerned with the technological, legislative, and environmental aspects of liquid waste disposal on land. These contacts have made available additional insights and concets other than those already in published form.

The completeness of the literature search was ascertained by consulting the "Abstracts of the Office of Water Resources Research", and the "Mechanized Information Center" (MIC) of the Ohio State University Library.

It is important to note here, that "land disposal of liquid wastes" is a poor term for designating all examples of this land use. The term "dispose" takes on the definition of applying large volumes of waste simply to get rid of the waste. Better terms would be "liquid waste renovation on land" or "liquid waste treatment on land". Both of these latter terms connote an attempt at planning and managing the land to make maximum use of soil physical, chemical, and biological processes for solving a waste management problem (the "living filter concept"). We thus will assume that in the future, disposal in reality will mean "renovation", or treatment. At the present time the installation of poorly designed septic systems, in soils unsuitable for receiving the wastes is an example of a waste disposal system rather than a waste renovation or treatment system.

Section 3

REVIEW OF FINDINGS OF PREVIOUS STUDIES

3.1 General Description of Land Use Category - A 13 Liquid Waste Disposal Areas

This study will evaluate the impact of the application of various liquid wastes to land on the pollution of ground and surface waters in the Great Lakes Basin. Consideration has been given to the following waste materials; municipal effluents and liquid sludges, industrial effluents and liquid sludges, water treatment plant sludges, septic tank effluents or effluents from other home waste treatment systems. By far the greatest potential impact to water pollution for the entire basin is associated with land disposal of municipal effluents and sludges, various industrial wastes, and septic tank effluents. This report will show this impact by focusing primarily on these areas.

There may also be some overlap with a few other land use categories e.g. municipal and some industrial sludges might reach the soil as solid wastes if mechanically dewatered prior to disposal. This overlap, however, should actually enhance the coverage in the overall report.

3.2 Length of time liquid waste disposal on land has been in practice.

Land disposal of wastes (although not necessarily as liquid wastes) is not new or novel and this concept has its roots in antiquity (Center for the Study of Federalism, 1972; Egeland, 1973). Disposal of human wastes or wastes generated from craft shops or primitive industries in early pastoral or nomadic societies did not present a severe problem because of the concimitant low population densities. However, industrialization with associated urbanization has resulted in a concentration of waste materials in limited geographical areas and has presented these societies with ever increasing problems of waste disposal. Likewise the technological changes within these societies have resulted in wastes e.g. cyanides, phenols, dyes, bleaching chemicals, salt brines from oil drilling operations etc. which were totally unknown to earlier societies.

During the early period of urbanization in the United States (during the mid to late 19th centry), those cities forward enough to consider disposal of wastes, utilized land application almost exclusively. This was true even though alternative methods such as septic tanks, Imhoff tanks, contact beds, trickling filters and activated sludge systems were developed during this period (Egeland, 1973). By 1910, however, many U.S. cities had adopted these "modern" methods

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(treatment) rather than for disposal of wastes. A workable definition would be that a potential pollutant is anything (element, compound, biological entity) that would have the potential to move through or off of the soil into ground water or surface water supplies and adversely affect the use of this water whether for drinking, industrial use, irrigation, or recreation. The design and management of the land treatment system will actually determine whether or not a potential pollutant will actually become a pollutant. The potential pollutants most often considered in land application systems are organic compounds, the biostimulants nitrogen and phosphorus, toxic organic compounds, heavy metal ions, a number of non-metallic inorganic elements and ions, and pathogenic microorganisms. Considerably more will be said about the mobility and hazards associated with these waste constituents in subsequent sections.

A series of recent publications have provided considerable analytical data on the composition of municipal wastewaters and effluents (Pound and Crites, 1973 a & b; Hunter and Kolalik, 1973; Ellis et al , 1972). The data from the report of Pound and Crites (1973 a) are reproduced in Table 3 and are representative of the other reports. For a detailed evaluation of effluent characteristics from a number of different secondary treatment processes see the excellent paper by Pound and Crites (1973 a).

Almost all of the organic matter of municipal wastewater effluents entered with the initial wastes or were formed during secondary treatment. The actual quantity of organic matter expressed as BOD or COD is not high since secondary treatment is about 90 percent effective in removing BOD. Relatively little information is available on the chemical analysis of the organic compounds of secondary effluent. The data which is available has been summerized by Hunter and Kotalik (1973). A portion of the readily decomposable organic materials (measurable by BOD) is derived from sludge particles carried over from the treatment system. These particles have a chemical composition similar to that of microbial tissue. Part of the BOD of wastewater effluents is also in the colloidal and soluble states and would probably differ little in composition from the particulate organic compounds. The remainder of the organic compounds of secondary effluent are commonly called refractory organics and are estimated by the difference between the value of COD and BOD. As the name implies these organic compounds are those which are considered more slowly degradable e.g. phenols, detergents, fats and waxes, hydrocarbons, cellulose, lignin, tannin plant bile pigment and humic compounds. It is this latter group of compounds which might be considered potential pollutants.

The inorganic constituents of wastewater effluents are largely soluble, and reflect closely the inorganic composition of the water supplies of the area. The exception to this is in municipalities where industrial wastes reach the sanitary system. Here heavy metals and ions such as Na^+ may be greatly enriched beyond that of the incoming water. Table 4 taken from data from the American Chemical Society (1969) reflects the inorganic constituents added to the initial supply during one cycle of water use. Nitrogen, phosphorus,

Table 1. Municipalities Within States of the Great Lakes Basin Applying Wastewaters on Land. (Confirmed)

Location	Pop Served	Year Started	Average Sewage Flow (mgd) ‡
Cassopolis, Mich.	2,100	1966	0.015
East Jordon, Mich.	2,041	1972	0.25
Harbor Springs Area, Mich.	3,500	1972	0.5
Harrison, Mich.	1,500	1971	0.07
Middleville, Mich.	1,865	1970	0.025
Ottowa Co. Rd. Comm., Mich.	80	1969	0.008
Roscommon, Mich.	808		-
Muskegon, Mich.	170,000	1973	**
Belding, Mich.	2,000	1972	0.20
Leoni Twp., Mich.	9,000	1971	0.90
Wayland, Mich.	5,000 (1990)		0.50
Vermontville, Mich.	-	1972	0.36
Spring Green, Wisc.*	1,200	1939	-
State College-University Pk.,Pa.*	37,000	1963	3.7
Napoleon, Ohio	7,790	1965	4.5
Milton, Wisc.	1,670	1939	0.4
Westly, Wisc. *	1,540	1958	0.174

* Not in basin

** Includes some flow from industries

‡ 1 mgd=3785.4 m^3/day

Table 2. Industrial Plants Within States of the Great Lakes Basin Applying Wastewaters on Land

Name and Location	Pop. Equiv.	Year Started	Ave. Flow (mgd)‡
Celotex Corporation Lagro, Indiana	8,400	1971	0.18
Commercial Solvents Terre Haute, Indiana	106,000	1965	0.07
Celotex Corporation L'Anse, Michigan	73,500	1966	0.6
Gerber Products Company Fremont, Michigan	39,200	1953	0.8
Michigan Milt Prod. Assoc. Ovid, Michigan	30,000	1964	0.25
Simpson Lee Paper Co. Vicksburg, Michigan	9,400	1971	3.2
Pet Milk Co. Biglerville, Penn.	64,200	1941	0.205
American Stores Dairy Co. Fairwater, Wisc.	-	1962	0.4
Libby, McNeill & Libby Janesville, Wisc.	39,000	1952	0.75
Deeds Bros. Dairy, Inc. Lancaster, Ohio	-	-	-
Libby, McNeill & Libby Liepsic, Ohio	-	1971	0.666
Sharp Canning, Inc. Rockford, Ohio	-	1954	0.080
Alto Coop. Creamery Astico Wisc.	-	1961	-
Cobb Canning Co. Cobb, Wisc.	-	1960	0.200
Frigo Cheese Corp. Wyocena, Wisc.	-	1956	-
Green Giant Co. Fox Lake, Wisc.	-	1955	1.000
Green Giant Co. Ripon, Wisc.		1955	0.700
Green Giant Co. Rosendale, Wisc.	-	1955	1.000
Hoffman Corners Coop Creamery Kendall, Wisc.	-	-	-
Kansas City Star Co. Park Falls, Wisc.	-	1952	0.300
Kimberley Clark Niagara, Wisc.	-	1958	1.320
Loyal Canning Co. Loyal, Wisc.	-	1950	0.060

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Name and Location	Pop. Equiv.	Year Started	Ave. Flow (mgd)
Mammoth Spring Canning Oakfield, Wisc.	-	1946	0.459
Oconomowoc Canning Co. Sun Prairie, Wisc.	-	1953	0.260
County Line Chees Co. Auburn, Indiana	-	1958	0.05
Graham Cheese Corp. Elnora, Indiana	-	1960	-
Pure Sealed Dairy, Inc. Ft. Wayne, Indiana	-	1960	0.09
Holland Dairies, Inc. Holland, Indiana	-	1967	60
Watervliet Paper Co. Div. of Hammermill Paper, Michigan	-	1972	1
Campbell Soup Co. Napoleon, Ohio	-	1954	5
Howard Paper Mills, Inc. Urbana, Ohio	-	1965	0.66
H.J. Heinz Co. Chambersburg, Penn.	-	1950	0.2-0.9
Knouse Foods Co-op, Inc. Peach Glen, Penn.	-	1965	0.172
Masonite Corp. Towanda, Penn.	-	1966	0.450
Baker Canning Co. Antigo, Wisc.	-	-	0.4
Dairy Maid, Co-op Augusta, Wisc.	-	1956	0.2
Country Gardens, Inc. Gillett, Wisconsin	-	-	0.2
Hillside Dairy Cadott, Wisc.	-	1956	-
John Wuetrich Creamery Co. Greenwood, Wisc.	-	1904	0.06
Stokely-Van Camp, Inc. Horicon, Wisc.	-	1972	0.12
Mindoro, Co-op Creamery Mindoro, Wisc.	-	1954	0.03
Flambeau Paper Co. Park Falls, Wisc.	-	1952	0.1
Shiocton Kraut Co., Inc. Shiocton, Wisc.	-	1962	0.009
Garden Valley Co-op Creamery Waumandee, Wisc.	-	1955	0.012
Waunakee Canning Co. Waunakee, Wisc.	-	1925	0.43

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Name and Location	Pop. Equiv.	Year Started	Ave. Flow (mgd)
Joan of Arc Co. Princeville,-Peoria, Ill.	-	1966	0.500
Joan of Arc Co. Hoopeston-Vermilion, Ill.	-	1972	0.200
Green Giant Co. Belvidere, Ill.	-	1949	2.000
Campbell Soup Co. Saratoga, Ind.	-	1972	0.050
Popejoy Poultry Logansport, Ind.	-	1964	0.01/wk
Weston Paper & Mfg.Co. Terre Haute, Ind.	-	1961	0.200
Duffy-Mott Co., Inc. Hartford, Mich.	-	1967	276.000
Simpson Lee Paper Co. Kalamazoo, Mich.	-	1971	3.500
Borden Co., Comstock Foods Waterloo, N.Y.	-	1968	0.170
The Beckman & Gast Co. Mercer, Ohio	-	1957	0.065
Crown Zellerback Baltimore, Ohio	-	1960	750.000
Morgan Packing Co., Inc. Warren, Indiana	-	1925	0.1

* 1 mgd = 3785.4 m^3/day

and land treatment methods were considered as less desirable alternatives for waste disposal. Waste treatment and disposal on land was not totally abandoned during this period and municipalities and industries continued to utilize land systems with some success (Center for the Study of Federalism 1972; Pound and Crites, 1973; American Public Works Association, 1973). Land disposal of untreated or partially treated wastes (sewage farming) in foreign countries remained more popular with Paris, Berlin, Mexico City and Melbourne, Australia the most notable example of systems still operative today.

During the first half of the twentieth century, the majority of remaining land disposal sites were located in Western United States. This occurred because increased land value and increased population pressure led to the abandoment of irrigation sites in Eastern United States. In addition the value of sewage wastewaters for crop irrigation and ground water recharge in the arid and semiarid regions of our Western States became readily apparent. Application of wastewaters, both industrial and municipal, to soils in the humid high rainfall area of the Great Lakes Basin has not been as common as in the Western United States (Table 1 and 2). These data also show that almost all of these operations have been initiated within the past two decades, and the majority within the past decade. It seems apparent that only now, in an era of renewed interest in the use of land for liquid waste disposal, or waste renovation, may we find that land application of wastes to soils of the Great Lakes Basin may become a highly significant alternative for waste treatment and renovation. More will be said about the reasons for this change in subsequent sections.

Widespread use of septic tank systems began in the post World War II era and in developing urban areas and rural areas. The continual construction of homes away from municipal sewage systems has and still makes these septic systems of continuing importance throughout the United States. Their relative use throughout the Great Lakes Basin is undoubtedly comparable to elsewhere, but accurate figures on numbers of installations is difficult to obtain.

3.3 Types and nature of pollutants associated with liquid waste applications to land.

The types of pollutants reaching the soil surface will differ greatly from municipality to municipality and from industry to industry. The degree of waste treatment, the treatment process itself and the nature of the community and industry contributing wastes all significantly effect the pollutants present in the wastewaters and sludges.

Perhaps it would be most useful when discussing land disposal or land treatment systems for wastes to use the term potential pollutant rather than pollutant. Such a term would and should emphasize the value of considering the soil as a "living filter" (Sopper and Kardos, 1973) and the desirability of using soils for renovation of wastes

Table 3. Municipal Wastewater Characteristics (From Pound & Crites, 1973, Vol. 2)

	mg/l (except as noted)		
Constituent	Untreated sewage (1)	Typical secondary treatment effluent (2)	Actual quality applied to land (3)
Physical			
Total solids	700	425	760-1,200
Total suspended solids	200	25	10-100
Chemical			
Total dissolved solids	500	400	750-1,100
ph, units	7.0± 0.5	7.0± 0.5	6.8-8.1
BOD	200	25	10-42
COD	500	70	30-80
Total nitrogen	40	20	10-60
Nitrate-nitrogen	0	--	0-10
Ammonia-nitrogen	25	--	1-40
Total phosphorus	10	10	7.9-25
Chlorides	50	45	40-200
Sulfate	--	--	107-383
Alkalinity ($CaCO_3$)	100	--	200-700
Boron	--	1.0	0-1.0
Sodium	--	50	190-250
Potassium	--	14	10-40
Calcium	--	24	20-120
Magnesium	--	17	10-50
Sodium adsorption ratio	--	2.7	4.5-7.9
Biological			
Coliform organisms, MPN/100ml	10^6	--	2.2-10^6

Sources:

Column 1- Medium strength (Metcalf & Eddy, Inc. Wastewater Engineering McGraw Book Co., N.Y. 1972).

Column 2- CRREL Special Report 72-1.

Column 3- Range of values obtained from site visits.

Table 4. Inorganic Constituents Added to Effluents Through Domestic Use. (American Chemical Society, 1969)

Constituent	Average Increment Added
	mg/l
Group I	
Sodium	70
Potassium	10
Calcium	15
Magnesium	7
Chloride	75
Bicarbonate	100
Sulfate	30
Silica	15
Hardness (as $CaCO_3$)	70
Alkalinity (as $CaCO_3$)	85
Group II	
Phosphate	25
Ammonium	20
Nitrate	10
Nitrite	1

heavy metals, sodium, boron, and chloride might be considered the most serious potential pollutants.

The pathogenic organisms present in wastewater effluents originate in the sewage entering the treatment plant. Among the common pathogens found in these waste materials are the bacterial pathogens, *Salmonella Shigella*, *Mycobacterium*, and *Vdbrio comma*; the hepatitis viruses, enteroveruses, and adenoviruses, the protozoan, *Endomoeba histolytica*, various helminth ova (Foster and Englebrecht, 1973) and pathogenic fungi (Cook and Kabler, 1955). All large scale proposals for land application of secondary effluents include plans for prior disinfection of effluent. Most smaller municipalities would also be required by state regulations to provide adequate disinfection for effluents being applied to land. Yet the potential for a health hazard created by pathogens within liquid wastewater during or after land application remains a concern. This is true because disinfection of effluents may not be uniformily effective against all pathogens (Hunter and Kotalik, 1973, Dunlop, 1968) and effective day to day disinfection may be limited by human and mechanical failure.

Many of the same potential pollutants associated with the disposal of wastewater effluents may be present in septic tank effluents and liquid sewage sludges applied to land. Analytical data on the composition of septic tank effluents (Thomas and Bendixen, 1969) and sewage sludges (Page A., 1973, Peterson, *et al*, 1973; and Dean and Smith, 1973) have recently been compiled. Representative data are provided in Tables 5 and 6.

In general, the septic tank effluent will have a higher biological oxygen demand (BOD) and potentially higher population of pathogenic bacteria than secondary effluents applied to land. The latter case results because no attempt is made to disinfect septic tank effluents before reaching the soil. Since septic tanks normally service private homes or farmsteads rather than industry, the content of potentially toxic metals or environmental toxins should not be a problem. Because of the high BOD and associated organic material the hazard of excess nitrogen and phosphorus reaching ground and surface water is great.

Sewage sludges are liquids containing inorganic and organic constituents removed from wastewaters by physical, chemical, or biological processes. In many respects sludges contain the same constituents as wastewater effluents only in a considerably more concentrated form. The organic matter content of sludges is normally high (20-35% carbon, 40-70% volotile solids) and therefore have very high biochemical oxygen demands. Sludge solids are also high in nitrogen (3.5-6.4%) about half of which is ammnonium nitrogen (Peterson *et al*, 1973). Nitrogen in sewage sludges represent a potential pollutant of ground and surface waters when applications of sewage sludges to land provides more minerolizable nitrogen than can be readily used by the crop (Miller, 1973 a 1973 b). Sewage sludges contain variable but generally high concentrations of phosphorus and heavy metals (Peterson *et al*, 1973; Dean and Smith 1973; Page, 1973) Although the soil is capable of retaining and inactivating P and heavy metals rather affectively (CRREL Report, 1972)

Table 5. Chemical analyses of sewage sludges from various wastewater treatment plants (Peterson et al, 1973)

			MSDGC, Chicago, Ill.				
Source	Hastings, Minn.	St. Paul, Minn.	Hanover	Calumet	West-Southwest	Denver Colo.	Athens Ga.
Treatment Process:	Primary and waste activated: anaerobic digestion without supernatant drawoff	Primary and waste activated (1:2): undigested	Primary and waste activated: anaerobic digestion without supernatant digester drawoff	Primary and waste activated anaerobic digestion without supernatant digester drawoff	Waste-activated: $FeCl_3$ addition: vac. filtered: heat-dried	Primary and waste activated: $FeCl_3$ and lime: vac. filtered undigested	Primary anaerobic digestion
			Percent Dry Weight Basis				
Analyses	(1)	(2)	(3)	(4)	(5)	(6)	(7)
N-Total	5.84	4.69	5.57	5.20	6.37	4.57	3.5
NH_4-N	2.34	1.33	3.63	2.40	trace	-	-
P	2.61	2.20	2.59	3.90	2.49	1.75	0.75
K	0.27	0.24	0.68	0.55	0.41	-	0.22

Table 5. (continued)

Analyses	(1)	(2)	Percent Dry Weight Basis (3)	(4)	(5)	(6)	(7)
Ca	2.97	2.52	5.05	4.20	1.4	7.38	1.21
Mg	0.26	0.40	1.64	0.60	0.75	0.45	0.09
Zn	0.075	0.14	0.069	0.35	-	0.172	0.252
B	0.0013	0.002	-	-	0.002-0.04	0.00022	0.00199
Fe	0.45	0.76	2.22	3.68	5.32	1.48	-
Mn	0.015	0.039	0.07	0.14	0.012	0.0253	0.0199
Al	0.65	0.74	-	1.21	-	-	-
Cd	0.00079	0.036	0.0089	0.0125	0.028	-	-
Cl	-	-	0.12	0.74	-	-	-
Cr	0.390	0.067	0.019	0.112	0.362	-	-
Cu	0.12	0.065	0.062	0.088	0.11	0.0324	0.046
Ni	<0.001	0.015	0.032	0.020	0.034	-	0.0026
Pb	0.039	0.070	0.083	0.18	0.141	-	-

Table 6. Identifying Characteristics of Liquid Wastes (Thomas and Bendixen, 1969).

Characteristic	Concentration (mg/l) Septic Tank Effluent*
COD	220
BOD	93
Nitrogen	
Total-N	33.3
Organic-N	7.9
NH_3-N	25.4
NO_3-N	< 0.1
TSS	45
VSS	38
Chlorides	95
Alkalinity	390
	Range
pH	7.1-8.3

*One-year averages.

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both these groups represent a long term hazard in land application of sewage sludges.

Large quantities of pathogenic bacteria, helminth ova, and viruses are found in sludges from primary and secondary treatment systems (Foster and Ergelbrecht, 1973). These raw sludges would constitute a pollution and health hazard if disposed of on land without further treatment. However, anaerobic digestion (Foster and Engelbrecht, 1973; Dean and Smith, 1973) lime treatment (Dean and Smith, 1973), chlorination (Green, 1972), and pasteurization (Dean and Smith, 1973) markedly reduced population of pathogens, viruses, ameoba and helminth ova.

Sewage sludges will also contain varying concentrations of inorganic and organic compounds which are considered potential environmental toxins. Among the compounds frequently found are phenolic compounds, chlorinated hydrocarbon pesticides and chlorinated biphenyls, detergent residues like ABS and NTA , petroleum products, heavy metals, etc. The concentrations of any one of these compounds reaching the soil during applications of liquid sludges would depend upon the industries using the sanitary system, degree of industrial pretreatment and the efficiency and type of municipal waste treatment facility. Various soluble inorganic constituents of sludges result in high salt content and electrical conductivities (Miller, 1974). Some ions such as sodium, boron, chloride, and sulfate could severely alter water quality in some instances. More will be said about the pollution potential of these sludge components in subsequent sections.

The nature of industrial wastes is quite different from that of municipal sanitary wastes. Industries discharge such diverse potentially toxic elements such as cyanides, acids, phenols, fluorides, dyes, animal by products, oils, acetaldehydes, acetones, sulfate liquor, wood sugars, bleaching chemicals, fungicides, slimicides, surface riding foams etc. (Zwick, 1971). The individual concentration of any of these constituents and the application rate to land will determine their pollution potential. Likewise, industrial wastes (food processing, paper industries, etc.) often produce wastes with very high biochemical oxygen demands(BOD),far exceeding municipal effluents. The high levels of toxic compounds and high BOD loading combine to make generaliztion on the pollution hazards of industrial wastes applied to land most difficult. (Table 7.)

3.4 State of the art in assessing and quantifying pollution problems associated with land application of liquid wastes.

At the present time "there is a paucity of quantitative information in the literature on the removal efficiencies of soil systems with respect to wastewater constituents" (Pound and Crites, Summary statement, Vol. I, 1973). Pollution problems associated with the myriad of individual home waste treatment systems, although considered commonplace are

Table 7. Characteristics of Various Industrial Wastewaters Applied to the Land (From Pound and Crites, Vol. 2, 1973)

Constituent	Food processing	Pulp and paper	Dairy
BOD, mg/l	200-4,000	60-30,000	4,000
COD, mg/l	300-10,000	--	--
Suspended solids, mg/l	200-3,000	200-100,000	--
Total fixed dissolved solids, mg/l	1,800	2,000	1,500
Total nitrogen, mg/l	10-50	--	90-400
pH	4.0-12	6-11	5-7
Temperature, deg C	62.8	90.5	--
, deg F	145	195	--

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even more difficult to quantify. It seems logical to conclude that the primary reason for this lack of information is a reflection of societies rather recent consideration of environmental concepts and problems. The majority of municipal and industrial land application systems designed during the past two decades or longer, reflected this environmental apathy, and did not provide for adequate monitoring of renovation efficiency.

The need for information on the possible pollution problems associated with land application of wastes is great and immediate. Most of the proposed land wastewater and sludge treatment projects in the planning stage are being designed to minimize ground and surface water pollution. These projects will only be as effective as the information used to make design predictions.

There are three approaches presently available for assessing and quantifying present and future water pollution problems associated with practices by which liquid wastes are applied to land. The first approach is to study established facilities employing land application of domestic and industrial wastewater and sludges. During the past two years three major reports have tabulated performance data on a relatively large number of existing sites at home and abroad. Although there has been some duplication the overall result has been to greatly increase our knowledge of operational success.

The first of these surveys, the 1972 report by the Temple University Center for the Study of Federalism, *Green Lands-Clean Streams,* included 35 existing and 3 proposed land treatment facilities for effluent in the United States. Some of these such as the Flushing Meadows, Arizona rapid infiltration site, the Pennsylvania State University spray irrigation site, and the Paris, Texas overland flow site have been designed to monitor their impact on ground and surface water quality. Although a number of sludge application sites are described, little information on their impact on water quality is provided.

The second major report is the Metcalf and Eddy study for the U.S. Environmental Protection Agency entitled *Wastewater Treatment and Reuse by Land Application*, Vol. 1 and 2 (Pound and Crites, 1973). This report provides reasonably detailed summaries of the operation of land application facilities by 10 municipalities and 11 industries. Limited information is provided on the effect of these facilities on water quality since these data were not available.

The third significant contribution the American Public Works Association Foundation report, *Survey of Facilities Using Land Application of Wastewater*, (1973), supplies on-site, in-depth investigations of 67 municipal and 20 industrial land application systems, and summaries of questionare data from an additional 86 municipal and 36 industrial sites utilizing land application for wastewater treatment and disposal. An additional 136 municipal and industrial land application sites were verified as presently operative but little additional information was provided.

The total amount of information from these reports is most valuable, but does not provide sufficient data for a thorough evaluation of the impact of applying wastewater and sludge to land on environmental quality. Their main value may be to identify existing land treatment locations so that detailed studies can be initiated on selected sites.

The second procedure for evaluating and quantifying pollution problems is to provide for detailed monitoring of ground and surface water quality as well as soils at new and future land treatment installations. As an example it is possible to point out that the new Muskegan, Michigan Wastewater Management System is being subjected to extensive monitoring activities for all potential water pollutants. Likewise it has been proposed that many "early action" sites related to the Alternative Wastewater Management Studies of the U.S. Army Corps of Engineers (Detroit and Southeastern, Mich.; Cleveland-Akron and Three Rivers Watersheds; and Chicago Studies) incorporate adequate provisions for monitoring wastewater quality.

The third approach is that of identifying research needs and carrying out the necessary research in an attempt to provide the answers. At the present time the task of identifying research needs associated with application of wastes to land is being actively pursued under the sponsorship of a joint committee of the USDA, EPA, and the National Association of State Universities and Land Grant Colleges. As a result of this committees efforts, a workshop was organized in July, 1973 in Champaign, Illinois to discuss all aspects of liquid effluent and sludge application to the land and to focus on research needs. The proceedings of this workshop, Recycling Municipal Sludges and Effluents on Land, have been published and contains the results of these deliberations. Other regional workshops are being planned to further discuss and refine research needs. It is hoped that adequate funding to support the designated high priority areas will be forthcoming.

The need for research, demonstration or monitoring programs to reduce the pollution potential of land treatment systems are discussed in greater detail in Section 6.

3.5 Mechanisms and agencies of transport of potential contaminants and pollutants within soil-water, ground-water, and surface-water systems.

The next section (3.6) will discuss in reasonable detail the physical, chemical and biological processes and interactions of the soil mantel which influence the renovation of wastewaters and sludges. Of the myriad of waste constituents applied to the soil with liquid wastes in land treatment systems, most are retained within the soil, often in the surface few centimeters. Some constituents such as the anions chloride, sulfate, nitrate, borate and fluoride are only weakly adsorbed and highly mobile and will move into groundwater if sufficient infiltration

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occurs. Others such as the common cations sodium potassium, calcium and magnesium will rather rapidly reach an equilibrium with the soil exchange sites and will eventually be present in the infiltrating water at the same concentration as in the wastewater. Since the water which infiltrates may eventually become groundwater, the concentration of these mobile consitutents within the wastewaters reaching the soil surface is of considerable importance to future groundwater quality. The U.S. Public Health Service has recommended maximum level for Total Dissolved Solids (TDS) of 500 mg/l in public water supplies.

Before discussing movement of potential pollutants in groundwater systems, it is appropriate to discuss briefly the different methodologies by which wastewater are applied to land treatment sites (Pound and Crites, 1973 b). These methodologies differ greatly in the amount of water which will infiltrate into groundwater, surface water supplies, or be lost by evapotranspiration. The method of application for liquid sludges will not greatly influence infiltration since the quantity of water applied will not normally be large. The balance of evapotranspiration vs precipitation, soil waterholding capacity, infiltration capacity, permeability, etc. are factors which will influence the movement of pollutants into ground-water from sludge application sites as well as land disposal systems for individual homes (Flach, 1973).

The *infiltration-percolation, or rapid infiltration* method applies high rates of wastewater (feet/week) into soil infiltration basins possessing high infiltration and percolation rates. This process is most commonly employed in water deficient areas of southwestern United States. The most well known example of this approach is the Flushing Meadows installation in the Salt River bed of west Phoenix (Bouwer, 1973 a & b).

The *spray-runoff, or overland flow* approach applies wastewaters to the top of a slope, with the renovation occuring as the water flows downslope. The application rate is measured in inches per week. The best know installation of this type is that of the Campbell Soup Company of Paris, Texas (Law *et al*, 1970). Campbell Soup Company has a similar installation at Napoleon, Ohio which is within the Great Lakes Basin.

The third technique is *irrigation*, commonly by *spray irrigation*, of controlled quantities of wastewater which is allowed to infiltrate and percolate through the soil. Application rates are much lower than the infiltration percolation method and are in the range of inches/week. This approach is the one most frequently employed. The Pennsylvania State University facility is probably the best known land treatment system employing spray irrigation (Parizek et al, 1967). Other useful methods of irrigation are ridge and furrow and flood irrigation.

Ground water, once contaminated, may remain in a deteriorated or usuable state for decades. This is not entirely due to the high mobility of selected chemical substances, but rather is related to the slow migration of ground water itself. Ground water moves from areas of recharge to zones of discharge in response to differences in hydraulic head. The rate of movement is largely controlled by the permeability of the strata and the hydraulic gradient, both of which are relatively low in most natural situations. As a result, ground-water velocities commonly range from about 1.5 meters (5 ft.) per day to as little as 1.5 meters (5 ft.) per year.

Shallow ground-water reserviors, in the majority of cases, are recharged over wide areas owing to the infiltration of precipitation. The most common zones of discharge are springs, seeps, lakes and streams. Consequently the contamination of a ground-water reservior could well lead to the contamination of a surface-water supply. Fortunately, however, the movement of ground water is so slow and the dilution so great, both in the ground and at points of discharge, that the increase in mineralization in a stream might amount to only a few milligrams per liter. Exceptions occur in areas where grossly contaminated ground-water discharges into a stream characterized by small flows. Water-quality problems such as these most commonly occur during dry-weather flow conditions in late summer and early fall.

A more complete discussion of hydrological factors important in land treatment systems is provided by Parizek (1973).

3.6 Natural renovation mechanisms available to remove pollutants and contaminants from liquid wastes applied to land.

The soil matrix provides a complex series of physical, chemical, and biological processes and interactions which contribute to the renovation of wastewater and liquid sludges. This collective activity has been likened to that of a filter and the term "living filter" has been coined to describe the renovation of liquid wastes by the soil mantle and associated vegetation (Kardos,1967; Kardos et al, 1968). The primary processes involved are filtration, ion-exchange, adsorption, precipitation, chemical and biological oxidations and reductions, and ion uptake by plants. Those waste constituents which are of primary importance to water quality and which are removed with varying success by the soil "living filter" are suspended solids, organic compounds, nitrogen, phosphorus, heavy metals, certain other inorganic ions, and various pathogens.

The different modes for applying of wastewaters to land treatment sites have been discussed briefly in the previous section (3.5). Likewise, there are distincly different methods of applying and incorporating liquid sludges (White et al, 1974). Each of these approaches differ regarding the manner in which the waste constituents will interact with the living filter. Yet the basic mechanisms of renovation ramains the same.

3.6.1 Removal of suspended solids

Suspended solids of wastewater, or particulate sludge components may be either inorganic or organic. Inorganic solids when effectively filtered remain as part of the soil matrix. Organic solids whether organic compounds or viable microbial cells will be held until destroyed by microbial catabolic processes or converted into the relatively stable humic materials.

The mechanism by which the soil functions as a physical filter have been discussed by McGouhey and Krone (1967) and Thomas (1973). The soil filter is comprised of a mixture of mineral particles of varying sizes, organic compounds (primarily soil organic matter), air and water. Primary soil particles and soil organic matter are associated in soil aggregates of varying size and stability. The pathway of liquid movement through the soil is thus through a series of pores and channels of varying size and stability. It is the size distribution of these pores and channels which controls the effectiveness of the soil to filter out suspended solids from liquid wastes. In most soils the pore size distribution and the nature of the water movement channels are such that suspended solids are completely removed after short travel distances in soils, i.e. the surface few centimeters. Only very coarse textured soils, or fine textured soils with severe internal cracking during drying cycles would not be effective physical filters. An additional filtering effect can be achieved by entrapment in vegetation on the surface of the soil. This mechanism is of particular significance in the spray-runoff or overland flow method of wastewater treatment.

Water movement through the soil is essential to the proper functioning of the soil filter. The effectiveness of the soil filtration system can be impeded by natural restrictions to hydraulic conductivity in medium to fine textured soils (Erickson, 1973; Flach, 1973). In some waste treatment systems, such as septic tank absorption systems, hydraulic conductivity can be reduced by soil clogging. This clogging is a physical clogging of the soil pores with suspended materials and microbial cells associated with organic overloading and prolonged anaerobic conditions (Jones and Taylor, 1965; Thomas et al, 1966; McGauhey and Krone, 1967). Soil clogging is not severe in land treatment systems managed to maintain aerobic conditions through intermittent application practices.

3.6.2 Removal of organic matter

One of the most significant functions of the microbial component of the soil filter is the degradation of organic compounds initially entrapped and adsorbed by the soil matrix. The decomposition of wastewater organic compounds in soil treatment systems have been discussed by Walcott (1972) and Miller (1973 a & b), the decomposition of septic

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tank effluent organics by Thomas and Bendixen (1969), the decomposition of sewage sludge organics by Miller (1973 a & b), and of some industrial wastes by Scott (1962) and Blasser and Owens (1964).

As might be surmised from a consideration of their variable chemical properties, organic waste compounds in soil decomposed at varying rates. A portion of the organic materials measurable by BOD are readily decomposed by the common biochemical pathways of glycolysis, the tricarboxylic acid cycle,B-oxidation, etc. The less readily decomposable organic compounds, or refractory organics, are estimated by the difference between the values for COD and BOD. Refractory organics consit of compounds such as phenols, detergents, fats and waxes, hydrocarbons, cellulose, lignin, tannin, plant and bite pigments, industrial pigments, pesticides, and humic compounds. Many of these such as some phenolic compounds, chlorinated hydrocarbon pesticides, detergent residues such as ABS and NTA, petroleum products etc. are considered potential environmental toxins. Normally the concentration of any one of these compounds reaching the soil would be low, and dependent upon the industries using the treatment systems and the treatment system itself. Most of these compounds will be adsorbed by the soil and held until microbial detoxication can occur. These reactions are discussed by Miller (1973 a).

Organic overloading can have a marked effect on the soil vegetation, soil clogging, and groundwater quality. Laboratory studies by Blosser and Owens (1964) with pulp and paper wastewaters showed that organic overloading can damage or kill vegetation, result in anaerobic conditions, or even in leaching of organic materials. Scott (1962) found that a loading rate of 2240 kg BOD/ha/day (2000 lb BOD/acre/day) resulted in a die back of vegetation and reduced soil permeability. Failure of septic tank soil absorption systems is often associated with poor operation of the septic tank which results in excessive organic loading (McGauhey and Krone, 1967). It is significant that organic overloading should not occur in well managed and designed land treatment systems for wastewater or from well operating septic systems. Application of anaerobically digested sewage sludge to soils will probably result in an accumulation of organic matter. However, the low hydraulic loading and stability of the organic matter to further rapid decomposition should not present any problems.

3.6.3 Nitrogen renovation.

One of the primary concerns associated with application of liquid wastewaters and sludges to land is the problem of maintaining the proper balance between additions and the nitrogen removal mechanisms of plant uptake and biological denitrification. Failure to do so may result in excess nitrogen leaching below the root zone and into groundwater and surface water supplies.

The primary forms of nitrogen reaching the soil from wastewaters

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and sludges are organic and ammonium nitrogen, although nitrate nitrogen may be present in some effluents (Pound and Crites, 1973). The initial reactions at the time of waste application to soils is the adsorption of organic nitrogen compounds (both soluble and partiulate) by physical and chemical processes, and the adsorption of ammonium ions on the cation exchange sites.

Following adsorption a portion of the organic nitrogen will be mineralized to amonium nitrogen. The extent of mineralization will be dependent upon the carbon:nitrogen ratio of the waste and the resistance of the organic nitrogen compounds to microbial activity. If the soil has remained aerobic, the mineralized ammonium nitrogen as well as any ammonium initially present will be rapidly converted to nitrate nitrogen. Adsorption and utilization of this nitrate by an actively growing agronomic crop or by forest vegetation is extremely important for the success of the soil filter. The significance of biological denitrification in land treatment systems for effluents and sludges, or in septic tank adsorption systems is not known with a great deal of precision. Estimates of nitrogen losses through biological dentrification based on greenhouse and lysimeter studies have averaged 15 percent (Allison, 1955). Larger losses up to 40 percent have been proposed in recent wastewater management studies to assure a favorable nitrogen balance (U.S. Army Corps of Engineers Wastewater Management Studies for Chicago Detroit and Southeastern Michigan and Cleveland-Akron and Three Rivers Watersheds). High moisture conditions and intermittent soil saturation would favor oxygen depletion and increased dentrification if a readily available source of decomposable organic matter is present. Biological dentrification could probably be increased by appropriate management of the land treatment system.

For a review of the numerous reactions relative to nitrogen renovation within land treatment systems see Hinsely et al (1971), Walcott (1972), Broadbent (1973), Miller (1973 a &b), and Lance (1973).

3.6.4 Phosphorous

Phosphorus will be present in secondary effluent (10 mg/l) primarily as orthophosphate; as the condensed phosphates, meta and polyphosphates; and as organic phosphate. Sewage sludges normally contain high concentrations of phosphorus (0.7-3.9 percent). Although the chemical identity of sludge phosphorus has not been determined it probably corresponds closely to that of secondary effluent.

There are three primary mechanisms which are important in phosphorus renovation within the soil "living filter". The first mechanism, crop removal can be expected to remove about 9.1 to 13.6 kg/ha (20 to 30 lbs./acre) of phosphorus per year (Parizek et al, 1967). At this rate of plant removal, a modest application rate of about 1028 to 1542 m^3 (10-15 acres-in) of secondary effluent with the normal level of phosphorus would supply the phosphorus needed by the crop. Crop removal would represent a negligible portion of the phosphorus normally added to soil with sewage sludge (Ellis, 1972). Precipitation reactions in soil are of two general types. At soil pH levels above pH 7.0 phosphorus will precipitate as calcium phosphates (Ellis, 1973). Dicalcium phosphate will form rapidly, octacalcium phosphate moderately slow (i.e. 2 to 3 months) and apatite forms of phosphate hardly at all. Dicalcium phosphate will be the form of P predominating at pH 7.0. This form of P will result in a solution solubility of about 7-8 ppm P at this pH. Lower solution concentrations of P could be obtained at acid pH where solubility is limited by the precipitation of iron or aluminum phosphates. However, an acid soil pH is undesirable for other reasons e.g. heavy metal solubility, and thus may not be maintained at land treatment sites. The major mechanism for removal of phosphorus is adsorption on soil materials. (Ellis and Knezek, 1972). Values obtained for phosphorus adsorption on soil using the Langmuir adsorption isotherm, generally fall in the range of 2 to 50 mg phosphorus per 100 g soil. Ellis (1973) has used these adsorption data to predict the quantity of phosphorus which could be adsorbed from solution by soils of defferent texture.

3.6.5 Heavy metals.

Wastewaters contain relatively low concentrations (Pound and Crites, 1973a;Blakeslee, 1973) and sewage sludges high concetrations of metallic cations (Blakeslee, 1973; Page, 1973; Dean and Smith, 1973; Peterson et al, 1973). The exact composition of these wastes is extremely variable and dependent upon the industry (if a separate treatment system), or industries contribution to the municipal sanitary treatment system. Some differences in compostion are related to the type of treatment process. Potentially toxic heavy metals Cd, Co, Cr, Cu, Ni, Pb, and Zn commonly occur in sludges and wastewaters. Their accumulation to levels toxic to vegetation grown on treatment sites is considered the long term hazard in land application of sewage sludges and wastewater. Conversely, eventual movement into groundwaters would be equally undesirable.

The initial reaction of heavy metals added with wastewaters and sludges, or released after microbial decomposition of the organic wastes will be adsorption on the soil exchange sites. With time, only small quantities will remain exchangeable as precipition reactions (phosphates, carbonates, hydroxides, or sulfides) will reduce their concetration far below that of other common exchangeable cations. In addition some metals will be chelated or complexed by both the insoluble soil organic colloids, as well as soluble natural or synthetic organic compounds. The soluble complexes or chelates will increase both the solubility and mobility of heavy metals in soils. In general metal ions tend to "revert" with time to chemical forms less available to plants. Reversion is usually favored in well drained soils with a neutral to alkaline pH.

In addition to the metals mentioned previously, large concetrations of Fe and Mn will be added with wastewaters and sludges. However, since Fe and Mn are very abundant in natural soils, the additions may not cause any specific or unusual problems. Iron and manganese will form highly insoluble oxides and hydroxides in well oxidized soils at neutral pH values. At low pH and under reducing conditions they can be solubilized and become mobile as Fe^{2+} and Mn^{2+}. This increased mobility can result in the formation of rather impervious iron and manganese pans in soils as well as deposits of inorganic hydroxides and microbial tissue which may plug tile drains. It is very important therefore, that land treatment sites be managed to assure adequate pH control and well drained conditions within the profile.

For further information and detail on the reactions of heavy metals in soils see Knezek (1972), Leeper (1972), Ellis (1973), Chaney (1973), Page (1973), and Lindsay (1973), and Ellis and Knezek (1972).

3.6.6 Boron and other dissolved solids

Wastewaters and sludges will add rather large concentrations of soluble salts mainly Na^+, K^+, Ca^{2+}, Cl^-, SO_4^{2-}, HCO_3^-. As discussed previously nitrification reactions in soils will also normally result in the presence of NO_3^-.

The cations Na^+, K^+, Ca^{2+} and Mg^{2+} will exchange with those already on the soil exchange sites. Since Na is frequently a dominant cation in wastes, both industrial and municipal, Na^+ may initially displace divalent cations held on the soil exchange complex. Eventually and rather quickly (in a few years) in non-calcareous soils the ions on the exchange complex will reach an equilibrium with the ionic distribution of the wastewater or sludge being added. After this equilibrium is reached the drainage water from soils receiving continued application of wastewaters will have a concentration of these cations similar to that of the applied wastewater. The amount of salts moving through soils to which sludges have been applied will depend on the quantity of excess water in the soil, whether from the sludge or rainfall, after evapotransperation losses. Whether the accumulation of these ions in ground or surface water supplies will present a problem will depend upon their distribution in the waste, the initial water quality, degree of dilution in groundwater or surface waters, and the established water quality standards.

Sodium ions may also adversely affect soil permeability, of considerable significance in effluent renovation on land where water movement into the soil is extremely important. Fine textured soils, high in expandable clays are particularly susceptible, because they swell appreciably as the exchangeable sodium percentage increases. Sodium adsorption ratios (SAR) have been used for a long time to evaluate the possible hazzards of irrigation water, and would be an applicable guide for wastewaters (Ellis, 1973).

Boron present as $H_3BO_3^{3-}$ is a special concern for land application of wastewaters. Boron is present in rather high concentrations in home or municipal wastewaters, a large portion arising from its use in detergents. Although boron can be adsorbed by various components of the soil matrix (Ellis & Knezek, 1972) it is assumed that the soil solution of the plow layer will be essentially at equilibrium with the added wastewater after about 1 years application of wastewater at normally proposed rates (Ellis, 1972). This may mean that boron will be leaching out in the drainage water at a concentration equal to or greater than that which is applied. An additional concern is that soluble boron could approach toxic levels for the vegetation associated with the land treatment site. Die back or reduced crop growth will greatly decrease the renovative capacity of the "living filter" for various ions, but particularly for nitrogen and phosphorus (See Sections 3.6.3 and 3.6.4).

Chlorides are often a significant component of wastewaters particularly for those industries which use salt (NaCl) in their processes. Chloride ion is not adsorbed by soils and will readily leach into drainage waters at a concentration near that of the wastewater. In certain areas, an eventual high concentration of chlorides in groundwater aquifers, might seriously limit the continued use of land treatment systems.

Sulfate will not normally present a serious problem in soils to which wastewaters are being applied. The reactions of particular importance are sulfate adsorption, leaching, and reduction to sulfides (Ellis, 1973; Miller, 1973).

3.6.7 Pathogenic microorganisms.

The potential health hazards associated with land treatment of municipal effluents and sludges without disinfection or with incomplete disinfection are the following: 1) the movement of pathogenic microorganisms through the soil filter in groundwater, 2) surface runoff carrying pathogens into surface water supplies; 3) contamination of edible portions of leafy vegetables and root crops during irrigation, 4) and aerosol transfer of pathogens during irrigation. Of the four areas listed above, the soil filter is of particular significance in the first two.

The initial soil reactions influencing the removal of pathogens from liquid wastes are physical entrapment and chemical adsorption by the soil, primarily at the soil surface (See Section 3.6.1). Once the microorganisms are retained the primary consideration is the length of survival of these organisms in the soil matrix. Must studies indicate a rather rapid die back of coliforms and bacterial pathogens reaching the soil so that the long term hazard to ground water or surface waters is considered minimal (Rudolfs, et al, 1950; Van Donsel, et al, 1967; McGauhey and Krone, 1967; Pound and Crites, 1973b).

Whether viruses die back at the same rate is still a matter of conjecture.

The mechanisms by which pathogenic and coliform microorganisms are eliminated from the soil are both abiotic and biotic. Abiotic factors considered important to the persistance of pathogenic microorganisms in soil are texture, moistue, pH, aeration, temperature and organic matter content. Soil microorganisms would indirectly effect these factors by altering pH, aeration, and organic matter content. Soil microorganisms directly participate in the elimination of pathogenic microorganisms by a mechanisms such as the production of microbial toxins; enzymatic lysis; predotory protozoa; parasitic bacteria, fungi, and phage; and the inability of the aleins to compete effectively with the indigenous community for nutrients (Miller, 1973 a)

The limiting factor in the elimination of all pathogens may be the effectiveness of the physical and chemical processes of the soil filter in retaining the pathogens long enough for their elimination by the soil microbial population. Movement through coarse textured soils could certainly provide a means to circumvent the effectiveness of the biological portion of the soil filter.

3.7 Probable changes in the future use of land for treatment of liquid wastes.

At this time it is impossible to accurately predict the future trend in the use of land for the treatment and renovation of municipal, industrial and septic tank waste effluents and sludges. There are a number of significant considerations both positive and negative, which will influence the future acceptance of the land treatment alternative. It is the authors opinion, however, that the primary weight of evidence points to a phenominal growth in the use of land treatment of wastes. As an example of positive activities in the Great Lakes basin we can list the U.S. Army Corps of Engineer Wastewater Management Studies for Chicago, Detroit and Southeastern Michigan, and the Cleveland-Akron and Three Rivers Watersheds. Although the public acceptability of the land treatment alternatives of these studies was poor, the studies did put forward land treatment for future consideration and provided useful exposure of ideas. Already, some smaller communities in these study areas are beginning plans to update their municipal waste treatment systems and are giving serious consideration to land treatment. Pierce (1973) has noted that while approximately 50 communities in Michigan have designed land treatment systems, only two have been in operation longer than one year. All of these 50 are proposed to be in operation by the end of 1974. The potential for growth can also be shown by considering that at the present time there are 16000 sewered communities in the United States serving 68 percent of the nations population. In the next 5 years 8000 of these communities are expected to construct new or upgraded or expanded facilities (Seabrook, 1973). It is likely, for many reasons to be discussed, that many of these communities may seriously consider the land treatment alternative. The remainder of this section will list and discuss the factors which will influence the acceptability of the use of land for waste treatment.

3.7.1 Factors presumed to positively influence land treatment activity.

1) The expected efficiency of removal of pollutants with well designed and managed land treatment methodology compares favorably with or exceeds those of advance physical, chemical, or biological methods of wastewater treatment (See Table 8). No other form of advanced wastewater treatment appears to be so effective in removing such a wide range of pollutants. Likewise, land application of sludges may also result in less of an environmental hazard than incineration, ocean dumping, or land fill, the alternative systems presently being used for ultimate disposal of sludges.

2) Land treatment systems for both municipal and industrial wastewaters and sludges are often cost effective when compared to alternative methods of treatment or ultimate disposal. This cost effectiveness factor could become even more significant if a requirement for advanced or tertiary treatment of wastewaters is adopted to reach our national goal

Table 8. Comparison of efficiency of waste treatment and disposal methods. (Westman, 1972)

	Percentage removed						
	Biological and chemical oxygen demand (BOD & COD)	Suspended matter	Bacteria	Viruses	Phos-phorus	Nitrogen	Heavy metals (cadmium, chromium, etc.)
Primary treatment							
Fine filters (screens)	5-10	5-20	10-20	0			
Settling tank	25-40	40-70	25-75	0	0-10	0-?	0
Secondary treatment							
Trickling filters	65-95	65-92	90-95	0-?	10-70(14)	50	0-10
Tertiary treatment							
Advanced chemical treatment	65-95(98*)	80-95(98*)	90-98(99*)	0-(90?) (14)	60-98	85	99
Soil filter (land disposal)	90-95(98*)	85-95(98*)	95-98(99*)	100?(18)	98	85	99 †

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*Environmental Protection Agency estimates, 1971.

† This is a possible maximum; toxic materials could accumulate in the crops or be lost to groundwater. Synthetic organic toxic materials are likely to be less well adsorbed by land than metals, since they evaporate to air more easily.

of zero discharge of pollutants to watercourses.

3) The Federal Water Pollution Control Act Amendments of 1972 contain specific provisions which make land treatment of wastes more attractive. These aspects of the Pollution Legislation are discussed effectively by Sullivan (1973).

Those providions which may be applicable to the Great Lakes Basin are:

Section 301 which requires that all publically owned treatment plants process their wastewaters so that effluent limitations based on secondary treatment are achieved by 1977. This requirement will result in large increases of sewage sludge which will need disposal in some manner, perhaps on land.

Title II of the Act authorizes a multibillion dollar program to assist communities with 75 percent Federally funded grants for constructing sewage treatment facilities. Such facilities specifically include land treatment facilities. In addition, the particular configurations and processes of any assisted sewage project must be chosen on the basis of the most cost effective method over the life of the works. As noted in point 2 above, this could provide an advantage to land treatment.

Sections 201 (d), (e) and (f) are extremely significant and read as follows:

"(d) The Administrator shall encourage waste treatment management which results in the construction of revenue producing facilities providing for---

(1) the recycling of potential sewage pollutants through the production of agriculture, silviculture, or aquaculture products, or any combination thereof:

(2) the confined and contained disposal of pollutants not recycled;

(3) the reclamation of wastewater; and

(4) the ultimate disposal of sludge in a manner that will not result in environmental hazards.

"(e) The Administrator shall encourage waste treatment management which results in integrating facilities for sewage treatment and recycling with facilities to treat, dispose of, or utilize other industrial and municipal wastes, including but not limited to solid waste and waste heat and thermal discharges. Such integrated facilities shall be designed and operated to produce revenues in excess of capital and operation and maintenance costs and such revenues shall be used by the designated regional management agency to aid in financing other environmental improvement programs.

"(f) The Administrator shall encourage waste treatment management which combines 'open space' and recreational considerations with such management.

Section 201 (g) (2)contains a provision which requires that any municipality or agency constructing, or planning new, remodeled or expanded treatment facilities will not receive grant funds unless they have reviewed appropriate wastemanagement alternatives and chosen "the best practical waste treatment technology over the life of the works". Land treatment systems will compete favorably in many circumstances as the best practical waste treatment technology .

Section 212, which covers definitions, specifically authorizes site acquisitions of the land that will be an intergral part of the treatment process or is used for ultimate disposal of residues resulting from such treatment. This provision will allow land used for land treatment to be an eligible cost in the grant. Conversely it will not allow the land upon which a conventional secondary treatment plant is located to be an eligible cost.

4) Land treatment of wastes is a process which can recycle water and significant waste constitutent such as carbon, nitrogen and phosphorus. Besides meeting societies newly acquired conceptual goal of recycling of all resources whenever possible, agriculture would benefit from the nitrogen and phosphorus present in wastes. Both of these nutrients may be in future short supply.

5) In this period of concern for energy usage and availability, the energy requirements associated with land application techniques may be substantially less than other means of waste treatment. Of the proposed alternatives, land treatment will require, the greatest amount of electrical energy, but the total energy requirements for most advanced and tertiary treatment proposals are high in comparison.

3.7.2 Factors presumed to negatively influence land treatment activities.

1) The requirements of the 1972 amendments to the Federal Water Pollution Control Act are so firm on the subject of monitoring that quality surveillance and control and a rigid program of reporting effluent quality will probably be enforced by Federal and State regulation agencies. The greater trouble and costs associated with this surveillance might actually result in the abandoment of some existing land treatment areas. In addition, additional controls could limit the acceptability of the land treatment concept for communities in the planning stage for new or expanded facilities. Septic tank and soil infiltration systems remain the most popular method for individual dwelling waste treatment. At the present time there is a great deal of effort being expended to provide adequate regulation of these systems and reduce their obvious pollution hazard. Regardless of whether this takes the form of land use legislation which restricts the soils utilized, or in the requirement more careful monitoring of their operation these regulations will reduce the number of conventional septic tank/soil

adsorption systems. Septic systems may be replaced by newly developed mechanical treatment devices.

2) Local public opinion may limit the acceptability of land treatment systems. Psychological concerns over the imagined distateful characteristics of effluents and sludges may limit the acceptability of some local installations but will severly limit the establishment of large urban land treatment systems. The experiences of the Corps of Engineers with public acceptance of the land treatments alternatives related to the Chicago, Detroit, and Cleveland Area Waste Management studies verify this concern. Experiences such as those with the "Prairie Plan" of the Metropolitan Sanitary District of Greater Chicago, (Dalton and Murphy, 1973, Barbolini, 1973) and Muskegon County Wastewater Management System (Postlewait and Knudsen, 1973) while documenting the problem also point out that public acceptance of large installations might be forthcoming.

3) Difficulties in obtaining the rights to the necessary land areas because of public resistance, higher land costs, and possible increased costs associated with the design and monitoring of land treatment systems to assure environmental acceptability and public health requirements, must be balanced against the construction cost, operating costs, and energy requirements of more conventional treatment alternatives. It is possible that under some circumstances land treatment systems could lose their apparent advantage of being cost effective.

4) Climatic influences within the Great Lakes Basin might severly restrict the applicability of the land treatment alternative. High rainfall, high humidity, and cold winter temperatures tend to complicate land treatment operations and reduce some of the more obvious advantages of irrigation and water conservation evident to the semiarid regions of the United States. Larger land area requirements necessary to accept large quantities of wastewater needing treatment and the increased cost for winter storage facilities are significant factors which might limit the feasibility of the land treatment alternative.

5) Adverse social and economic impacts of large urban land treatment systems e.g. partial loss of local tax base, removing of large amounts of agricultural land from private to public ownership, the necessity for the relocation of large numbers of people, etc. may limit the degree of community acceptance.

3.8 Projected Seriousness of Future Pollution Problems Derived From Application of Liquid Wastes to Land.

3.8.1 Land application of municipal and industrial effluents and sludges.

The overall fear that land treatment might pose a threat to public health and the environment are real, but seldom vocalized by the scientific community. They do, however, surface among the lay population when land treatment installations are reviewed at public hearings in an effort to gain public acceptance (See for example, U.S. Army Corps of Engineers, Wastewater Management Study for Cleveland, Akron Metropolitan and Three Rivers Watershed areas, appendix VIII, Public Involvement, 1973). The primary concerns are that the biostimulants (N and P), inorganic and organic toxins, certain soluble salts, and heavy metals present in wastewaters and might move through or off of soils into water supplies, that pathogens might also move in the same manner and cause disease or that aerosols containing pathogens might be formed during spray irrigation of liquid wastes. In addition there is still a large concern about the emission of malodorous gases. One severe critic of land treatment systems (Egeland, 1973) has also warned "that the extensive use of land disposal systems will result in the devastation of vast areas of land....".

Regardless of the fear and concern expressed the majority of available evidence is that no other form of advanced treatment for wastewater effluents (whether municipal or industrial) appears to be so effective in removing such a wide range of pollutants as is the soil "living filter". The relative effectiveness of land treatment methods is compared to conventional treatment processes in Table 8. The data available at this time and discussed in detail in Section 6 support these estimates that a properly designed and managed land treatment system for wastewater effluents can provide complete removal of BOD and COD materials; pathogenic bacteria,and viruses; phosphorus; detergent residues (ABS etc.); and heavy metals. High levels of treatment are found for nitrogen, sulfates, and chlorinated hydrocarbons. Various soluble salts such as boron, sodium, chloride, calcium which together are measured as total dissolved solids (TDS) are not removed as affectively by soil and may pose the greatest threat to water quality. Even then, if preliminary examination and subsequent monitoring detect a particular water quality problem, appropriate pre-or posttreatment stages could be incorporated into the system (Center for the Study of Federalism, 1972).

Liquid sludges present some of the same environmental concerns as effluents. However, as with effluents, a properly designed and managed land system for sludges, should not provide any risk to the environment. The most important conceptual idea is that soils are not disposal areas for sludges but must be managed for renovation and recyclying of sludge components. Heavy metal accumulation within the soil profile to a level which would be toxic to vegetation, or to animals or man consuming the vegetation growing on the sludge treatment site, is the most serious environmental concern. Survival of pathogenic microorganisms in the soil so that they would present a health risk by movement into ground and surface water supplies has also been a consideration. The concern for metals can be eleviated by removal prior to waste treatment (on-site), by controlling the rate of application, as well as by the selection and management of the soil. The potential problem with pathogens can be eliminated by disinfection of the sludge in pasteurization, lime treatment, and by preventing water and particle movement off of the land after sludge application. Finally, it should also be recognized that there may be some industrial sludges, or municipal sludges containg large industrial imputs, that cannot be safely applied to land. Any attempt to do so would be extremely hazardous.

If the projected operation of land treatment systems appear technically sound (with respect to pollution) the projected verbalization of this optimism is no less enthusiastic. Bahr, et al (1972) of Michigan State University in their evaluation of the Wastewater Management Alternatives for Southeastern Michigan grouped eight waste treatment alternatives in terms of their effectiveness in improving stream conditions in Michigan and Lake Erie based on their efficiencies for removal of toxic materials and biostimulants. The land treatment alternative was considered to perform best according to these criteria and thus ranked the highest. From an ecological standpoint, land application of sludge was considered a better alternative than incineration. The recycling of sludge components was considered as the most desirable aspect of this approach.

A similar conclusion was derived by the consultants concerned with the development of the Cleveland-Akron and Three Rivers Watershed Wastewater Management systems in Ohio. The ecological impact summary (U.S. Army Corps of Engineers, Wastewater Management, Study for Cleveland-Akron Metropolitan and Three Rivers Watershed Areas, Summary Report, 1973) indicated only positive ecological impacts of the land treatment alternatives with regard to pollutants. Dr. Ira Whitman, Director of the Ohio EPA was also enthusiastic about the effectiveness of the land treatment alternatives presented in this study. He responded that "After reviewing the Corps study, I believe I would have little hesitation in reviewing proposals for land disposal of adequately treated wastes from communities of less than 100,000 population in the same way I would review any other waste treatment plant design".

3.8.2 Use of land for renovation of effluents and sludges from individual home treatment systems.

While the environmental impact of properly designed land treatment systems for municipal and industrial sludges is considered slight, the same cannot be said for the smaller individual home treatment systems. Soil absorption systems for individual home treatment systems are being installed at an increasingly rapid rate, not only in suburbia, but also in recreational developments around both natural and man made lakes. At the same time it is widely recognized that the rate of their failure resulting in environmental pollution of groundwater and surface waters is all too frequent (Bouma, et al, 1972; Welker, 1974, Winneburger, 1972; Thomas, 1973). In many cases direct by-pass of the soil to drainage ditches or small streams and lakes has been the answer to a poorly functioning soil adsorption system.

A recent review (Patterson et al, 1971) cited shallow bedrock, impervious soil, high groundwater, overloaded soil, improper installation and poor maintenance as the most common causes of septic tank absorption system failures. Estimates from the U.S. Soil Conservation Service estimates that less than 32 percent of the land area in the United States is suited for soil absorption field installation (Wenk, 1971). Yet at the present time few areas have been able to exert the needed leadership or legal power to prevent the growth of a very serious pollution problem. It is apparent that the only solution to this problem is the adoption of a program of land use planning, the development of alternative approaches for individual home treatment of wastes, and the development of agencies for the supervision of the installation and maintenance of land absorption systems. None of these solutions even though adopted, would have an appreciable impact during this decade.

3.9 Review of Institutional Arrangements to Regulate Land Use, and Control Pollution from Liquid Waste Application to Land.

3.9.1 Nature of existing legislative regulation and enforcement program.

Federal and state legislation and regulations that relate directly to recycling municipal and industrial wastewater effluents and sludges on land is of fairly recent origin. Two rather recent reviews, Center for the Study of Federalism, Green Land, Clean Streams (1972), and the American Public Works Association Research Foundation report, Survey of Facilities Using Land Application of Wastewater (1973) have reviewed the various State and Federal regulations and opinions in considerable detail. Sullivan (1973) and Pound and Crites (1973 b) have smaller sections of significance in this general area.

Prior to the passage of Public Law 92-500, The Federal Water Pollution Control Act Amendments of 1972, there was no federal water legislation which related to land treatment. As noted earlier in Section 3.7, the wording of this legislation has done much to encourage and support consideration of the land treatment alternative for waste treatment. These regulations, however, while focusing on the problem of water quality improvements have made no attempt to provide specific guidelines for the design and operation of land treatment systems for effluent and sludges.

The surveys of the APWA (1973) and the Center for the Study of Federalism (1972) polled State Health and State Water Pollution Control Agencies about regulations governing land treatment of wastes. These studies indicate that (as of 1972) only 17 states had specific regulations concerning sewage irrigation, with only four states reporting roles governing the types of crops that can be grown on sewage irrigated land. By far the majority of the states indicated that they have no set policies on land treatment installations. In the absence of formal state regulations, some state agencies have used unofficial staff opinions as the basis of land application decisions.

The states within the Great Lakes Basin have until recently been those with little activity in regulating land treatment systems. This posture is perhaps expected since land treatment facilities have not been as prevalent as in other geographical areas of the United States. The expressed regulations of these states will be reviewed briefly in the following paragraphs. This information was derived primarily from the report from the Center for the Study of Federalism (1972).

Illinois- the state Environmental Protection Agency, Standards Section, have beeen utilizing the standards for land treatment put forth in Ground Disposal of Wastewaters, 1971. Addendum No. 2 to Recommended Standards for Sewage Works, Great Lakes-Upper Mississippi River Board of State Sanitary Engineers. These so called "Ten States

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Standards" are reproduced in appendix A. Even though a considerable amount of research activity with accompaning demonstration programs are presently going on in Illinois, particularly in the area of sewage sludge applications to land, the overall disposition of the state agencies to land treatment facilities is considered negative (Center for the Study of Federalism, 1972).

Indiana- Indiana has no regulations specifically covering land treatment facilities. The Water Pollution Control Agency of Indiana (AFWA report, 1973) considers each application for spray irrigation or ground water percolation as an individual problem. The overall disposition of Indiana to land treatment facilities is not known.

Michigan-At the present time Michigan has no regulations specifically dealing with land treatment of municipal wastes. The Michigan Liquid Industrial Waste Disposal Act (Act 136, Public Acts of 1969) prohibits the disposal of industrial wastes onto or into the ground except at locations specifically approved by the Water Resources Commission. A paper by Blakeslee (1973) indicates that the Michigan Department of Natural Resources is implementing a program of monitoring for land treatment systems within the State. Pierce (1973) has also provided some indication that the Michigan Department of Public Health is utilizing the "Ten States Standards", as guidelines for design of land treatment systems in the state of Michigan. The rapid growth in the number of municipalities and industries using land treatment in Michigan would suggest that more rigid guidelines might be developed.

Minnesota-The Minnesota Pollution Control Agency (MPCA) is the Statuatory Agency responsible for establishing reasonable pollution standards for waters within the state. At the present time the MPCA issues permits for land application of treated wastewaters based on a "Land Disposal-Recommended Design Guidelines", May, 1972, which they have developed. Prior to this time no state agency had actively regulated land application sites. The MPCA is presently developing guidelines applicable to disposing of sewage sludges on land.

New York-There are presently no official standards or regulations applicable to land treatment systems for wastewater. Each proposed facility is reviewed individually and considers topography, soil characteristics ground water depth, climatic conditions and type of cover crop. Land treatment of wastewater is permitted only during the growing season. Wastewaters high in non-biodegradable substances are not allowed to be discharged on the land. At present the New York State Department of Environmental Conservation is attempting to develop a more rational approach toward setting criteria for land treatment facilities.

Ohio-At this time Ohio does not have a law specifically dealing with land treatment systems. The Water Quality Standards of the Ohio Environmental Protection Agency, July 27, 1973 requires that "any industrial, source of wastewater discharge to high quality waters as part of the initial project design, to provide the most effective waste treatment available under existing technology". This wording which is similar to the federal legislation certainly provides an opportunity for the consideration of the land treatment alternatives Dr. Ira Whitman, Director of the Ohio EPA, in response to the recent Corps of Engineer Wastewater Management Study for the Cleveland-Akron and Three Rivers Watershed areas (Summary Report, 1973) has shown a favorable attitude to land treatment systems for cities with a population less than 100,000. The Ohio EPA has the authority to approve or disapprove individual plans for such treatment systems and are presently actively engaged in such activities.

Pennsylvania-At the present time no regulations exist specifically related to the use of land treatment for wastewaters and sludges. The Department of Environmental Resources has developed guidelines for spray irrigation of liquid wastes (Pennsylvania Spray Irrigation Manual, 1972) which is the most complete document of its kind available among the states within the basin. A new program to require permits of all spray irrigation installations is being implemented by the Bureau of Water Quality Management of the Pennsylvania Department of Environmental Resources (Rhindress, 1973).

Wisconsin-Wisconsin statutes also do not deal specifically with land treatment. No statements of formal or informal policy for land treatment was available from the Department of Natural Resources or Board of Public Health. Since a number of land treatment sites, both municipal and industrial, effluents and sludges are being operated, the State is considered to have a favorable orientation to land treatment systems.

Some regulations related to the design and installation of individual family dwelling sewage systems have been developed. For example, the Wisconsin State Board of Health (1969) regulations and sections of the Ohio Revised Code attempt to provide guidance in this important area. Another frequently used source of information has been the Manual of Septic Tank Practice of the U.S. Public Health Service. Unfortunatley, a great deal of authority has been vested in each local districts Board of Health. Because of this authority the design of home sewage systems and final effluent disposal requirements differs from area to area, throughout the region. In some areas control is nonexistent or poorly enforced. This fragmentation of authority is one reason that land treatment systems for individual home sewage systems are often malfunctioning and sources of environmental pollution.

3.9.2 Nature of new programs required to meet water quality objectives.

The United States-Canadian Great Lakes Water Quality Agreement of 1972 Federal Water Pollution Control Act Amendments have the goal of eliminating the discharge of pollutants into navigable Waters by 1985. These agreements and laws as well as other Federal laws and regulations on land, water, and air quality; public concern about the total environment; and potentially large Federal grant funds for waste treatment technology has stimulated the Federal government to be actively interested in land treatment. Federal enforcement of pollution control legislation, environmental concern, and an ever increasing concern with economy has also resulted in increased interest in land treatment by state and local government and certain industries. It is obvious from the previous section, that some states in the basin have not yet formulated adequate legislation regulations, and guidelines relative to land application of wastes. Even those states which have developed guidelines must be prepared to update and modify them as more scientific information becomes available to insure that the design, operation, and monitoring of land treatment systems will maintain or improve the quality of our water resources. It seems equally important that legislation be developed which applies to home sewage systems. Such legislation on the Federal and/or state level must provide guidelines for selection of proper soils, choices of the best methods of sewage disposal or treatment, soil pollution standards, off lot sewage waste discharge standards, and firm management procedures. Some concerted effort must be made to survey the magnitude of home sewage system failures and pollution hazards, either prior to or in conjunction with this legislation.

A number of general and specific objectives within the Federal Pollution Control Act Amendments of 1972 are indirectly related to planning land treatment areas and related problems of land use planning. These objectives emphasize comprehensive regional planning by encourageing area wide wastewater management planning, that wastewater management programs designed to control and treat all sources of wastes including point sources, non-point sources, and in-place or accumulated sources, and that wastewater management plans must be developed for waste treatment needs in the area for a 20 year period. Davis (1973) has provided further insights into the problems and advantages which may occur through area wide land use planning associated with land treatment sites. He has projected that the initiation of large treatment systems will alter the physical and political shape of the urban regions.

Section 4

RELEVANT ONGOING OR PROPOSED RESEARCH, DEMONSTRATION OR MONITORING PROGRAMS

The research and demonstration programs summarized in Tables 9,10,& 11 were selected because of their potentially greater applicability to the problems, soils, or climatic regimes of the Great Lakes Basin. Therefore numerous other research studies on land treatment of municipal and industrial wastes which are being conducted throughout the United States were not included.

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Table 9. Selected Research, Demonstration, or Monitoring Programs Evaluating Land Treatment of Municipal and Industrial Effluents.

Organization, Location and Dates of Operation	Sponsor	Principle Investigators or contact (where known)	Objectives and Comments
Penn. State Univ., State College & Univ. Park, Pa 1962	Hatch Funds H.E.W., FWPCA OWRR, and Penn. State Univ.	L, T. Kardos, and W.E. Sopper, Penn. State Univ.	1) To evaluate application and management techniques for renovating municipal secondary effluent on cropland and forests. 2) To evaluate the effectiveness of the soil "living filter" in renovating spray irrigation secondary effluent.
Muskegon County Wastewater Management System, Muskegan, Mich. 1973	Muskegon County Dept. of Public Works Federal and State of Michigan Grants, EPA	J. C. Postlewait Muskegan County Dept. of Public Works.	To evaluate land treatment of effluent and sludges as an alternative method of municipal and industrial waste management for an entire county. (Soils are not representative of fine textured soils of Great Lakes Basin).
Michigan State University Water Quality Management Project 1973	State of Michigan, Rockefeller Foundation, EPA	T. G. Bahr Inst. Water Research Michigan State University	1) To evaluate the effectiveness of soils for renovating lagoon treated wastewater. 2) To evaluate the effect of wastewater on yield and quality of different crops.
University of Minnesota St. Paul, Minnesota 1974	Corps of Engr.; USDA, ARS, and University of Minnesota	W. E. Larson, Dept. of Soil Science, Univ. of Minnesota	Watershed study on selection and management of agronomic crops for maximum nitrogen renovation from land applied secondary effluents. Should provide operational data in cold regions.

Table 9. (cont) Selected Research, Demonstration, or Monitoring Programs Evaluating Land Treatment of Municipal and Industrial Effluents

U.S. Army Corps of Engineers (1973)			
A) Hanover, New Hampshire	Corps of Engrs.	S.C. Reed, Cold Regions Research & Engineering Lab.	Develop and investigate performance of spray irrigation test cells.
B) Fort Devens, Mass.	Corps of Engrs.	Not known	Investigate the effectiveness of rapid infiltration basins.
C) Vicksburg, Miss.	Corps of Engrs.	P.G. Hunt	Greenhouse and laboratory experiments on the renovative mechanisms of infiltration percolation technique (overland flow).
D) Location not known	Corps of Engrs.	Not known	Analyze soil samples from Melbourne, Australia's sewage farm.
City of Belding, Michigan	EPA	Not known	Evaluate the effectiveness of renovating municipal secondary effluent on forest land.
Campbell Soup Co. Napoleon, Ohio 1954	None	Not known	Pioneer area in utilzing overland flow system.

Table 10. Selected Research, Demonstration, or Monitoring Programs Evaluating Land Treatment of Municipal Sludges.

Organization, Location and Dates of Operation	Sponsor	Principle Investigators or Contact (where known)	Objectives and Comments
University of Illinois Urbana, Ill. and Lysimeter Faculty Northeast Agronomy Research Center 1968	EPA and Metropolitan Sanitary Dist. of Greater Chicago	T.D. Hinesly and R. L. Jones, Dept. of Agronomy, University of Illinois, Urbana	To assess agricultural benefits and environmental changes resulting from the use of digested sewage on field crops. (Laboratory, lysimeter, and field plot studies)
Rutgers University & N.J. Agric. Exp. Station New Brunswick, NJ 1972	New Jersey Water Research Inst.	C.Reed, Dept. of Biological and Agric Engr., Rutgers Univ. and L.A. Douglas, Dept. of Soils & Crops, Rutgers Univ.	To evaluate methods of applying digested sewage sludges to land to assess the plant response & environmental effects of land treatment of sewage sludges.(Laboratory, greenhouse & field studies included).
University of Minnesota St. Paul	ARS & Univ. of Minnesota	W. E. Larson, Dept. of Soil Science, Univ. of Minnesota	Field studies to assess availability of sludge borne metals to various vegetable crops, yield responses of corn & various vegetables to sewage sludge treatments, and management practices to prevent pollution of surface and ground waters. (Anaerobic, aerobic, and waste activated sludges were evaluated).

Table 10. (cont) Selected Research, Demonstration, or Monitoring Programs Evaluating Land Treatment of Municipal Sludges.

University of Wisconsin, Madison, Wisconsin 1971	University of Wisconsin, City of Janesville, & Dept. of Natural Resources	D. R. Keeney, Dept. of Soil Science, University of Wisconsin	To determine the effects of sewage sludge on crop yields. To ascertain N mineralization from sludge organic nitrogen & subsequent residual nitrogen mineralization. To study the quantity and mechanism of heavy metal uptake by plants from sludge amended soils. (Field & laboratory studies).
The Soil Enrichment Corporation (SEMCO), Arcola, Illinois 1970	-	W. J. Bauer, Bauer Engineers, 20 N. Wacker Dr. Chicago, Illinois	To demonstrate the applicability of transporting and applying sewage sludge to land.
Purdue Agricultural Experiment Station, W. Lafayette, Ind. 1972	Purdue Agric. Exper. Station	L. E. Sommers, Dept of Agronomy, Purdue University	Determination of the chemical composition of municipal sewage sludges, and characterization of the nitrogen and phosphorus compounds and metal complexes. Basic studies of the N and heavy metal transformations in sludge amended soils.
ARS, USDA Laboratory Beltsville, Md.	ARS, Maryland Environmental Service, Bureau of Wastewater Treatment, D.C.	R. L. Chaney, ARS, USDA Beltsville, MD.	Laboratory, greenhouse & field studies on heavy metal reactions of soils and plants.

Table 11. Selected Research Program Related to the Design and Operation of Home Sewerage Systems

Organization and Location	Sponsor	Principle Investigators or Contact (where known)	Objectives and Comments
University of Wisconsin, Madison, Wisconsin	Wisc. Dept. of Natural Resources	J. Bouma, Dept. of Soil Science, University of Wisconsin	1) To evaluate the general problem of small scale waste disposal a) soil adsorption of septic tank effluents b) alternative mechanical methods of treating wastes.
University of Connecticut, Storrs, Conn.	State of Connecticut Research Foundation	R. Laak, Dept. of Civil Engineering, University Connecticut	To determine design paremeters for construction of septic tank/soil absorption systems for long term (indefinite) operation.

Section 5

NATURE AND AVAILABILITY OF TECHNOLOGY TO COPE WITH POLLUTION PROBLEMS

Pollution problems associated with existing municipal and industrial land treatment systems have been difficult to determine since few of them have been rigidly monitored (See section 3.4 and 3.8). The best judgment at this time would suggest that the impact of these installations on the water quality of the Great Lakes Basin has been negligible. The majority of published opinions would also suggest that any future pollution problems will also be negligible, even though the number of installations within the basin will probably increase dramatically (See Section 3.8).

Proponents of land treatment systems argue that we presently have the necessary knowledge and technology to properly design and manage land treatment systems to prevent environmental pollution. Newly designed and constructed systems have incorporated the knowledge of many disciplines e.g. geology, hydrology, climatology, agronomy, microbiology, and economics to minimize environmental hazards. Yet the discussions carried out and reported in the proceedings of a recent workshop (EPA,USDA, NASULGC, 1973) emphasizes that basic information and additional technology are still needed in some very significant areas, e.g. heavy metal interactions in soils and plants, nitrogen transformations in soils, survival and movement of viruses, etc. At the present time knowledge is expanding rapidly and should continue to improve in the next decade as additional research, demonstration, and monitoring programs reach fruition.

Large numbers of existing individual home sewage treatment systems utilizing soils for effluent treatment are subject to failure (See Section 3.8) and the impact on ground and surface water quality is considered locally severe. Yet, although the failures are often documented, their collective pollution impact within the Great Lakes Basin has not been estimated, and is not readily amenable to study. The primary reason for failure is poor soil properties which make it impossible for long term renovation of effluents. No-existing technology or design can successfully overcome these adverse soil properties. For this reason large areas of the Great Lakes Basin are in need of an alternative technology for individual home sewage systems which do not involove soil renovation. The direction and inforcement of future legislation will probably determine how rapidly this technology will be developed.

Section 6

NEED FOR NEW RESEARCH, DEMONSTRATION OR MONITORING PROGRAM

6.1 Gaps in knowledge pertaining to the successful use of land for treatment of liquid wastes (1973 and 1976)

There is already available a considerable accumulation of information from research and experience which is useful in designing and managing effective land systems for treatment of most municipal and industrial wastes (both effluents and sludges). This is especially true for the smaller communities and industries (pop. equiv. to 100,000 or less) where relatively small land areas and light application rates are involved.

We are not as fortunate when we consider septic tank systems or individual home waste treatment systems. Problems in operation and environmental pollution still exist with little overall movement to correct the problem. In actuality it may not be the problem of not understanding the technological principles involved in designing and managing individual home treatment systems which results in the recalcitrant problem. Rather it may be a lack of legal control, adequate inforcement of existing regulations and poor land use planning which make ground and surface water pollution from individual home treatment systems the persistent problem that it is.

Research needs in the area of land treatment of liquid wastes will be noted in the following paragraphs. Please note that the type of research needed in the future is that which will help us refine our original estimates of the expected longivity and associated pollution hazards of land treatment systems. Such refinement in our knowldege may well result in marked reductions in the construction, operation, and monitoring costs of land treatment systems and make them increasingly cost effective. Refinement of our understanding of the myriad of physical, chemical and biological reactions influencing the renovation of potential pollutants should also result in increased public acceptance of land treatment as a waste management alternative. Both of these points could bring about increased use of land treatment by larger metropolitan areas and plan a significant role in future land use planning e.g. reduce urban sprawl, greenbelts, etc. throughout the United States (Davis, 1973). At the present time, there is a great amount of research being conducted and numerous demonstration grants throughout the United States and the Great Lakes Basin dealing with land treatment of liquid wastes. Progress will be made in the next two years but it is doubtful if all of the questions raised will be answered by 1976. Unfortunately the data needed relates to long term effects of land treatment, and can not be ascertained by short term studies.

6.1.1 Effluents

Hydraulic conductivity - In the Great Lakes Basin, unlike the water poor arid or semiarid western regions, hydraulic conductivity of soils presents the greatest constraint to land treatment of waste effluents. Coarse textured soils with good hydraulic conductivity are not desirable for renovation of potential pollutants, which are present in waste effluents. The medium and fine textured soils which are more desirable for renovation have lower initial hydraulic conductivities which often decrease further during continuous irrigation. We presently have little information on or adequate techniques to measure changes in hydraulic conductivity in soils receiving large and frequent applications of effluent by spray irrigation.

There has been a tendency to underdesign drainage systems in soils in humid areas being used for liquid waste treatment (Erickson, 1973). These faulty designs undoubtedly occur because the only existing design data is based on agricultural drainage studies. Agricultural drainage design, because of economic constraints, have been designed to avoid catostrophic losses but will allow some yield reduction under severe weather situations. Since maximum plant growth and numerous microbiological reactions of the "soil filter" are dependent on aerobic conditions, even temporary periods of soil saturation could reduce the renovative capability of the soil. Present design criteria for drainage are certainly not adequate to renovate the maximum quantity of wastewater on the smallest amount of land. Improvement in design must be made if land treatment plans for effluents from major metropolitan areas e.g. Chicago, Detroit and Cleveland-Akron are ever to be implemented.

Nitrogen transformations - Nitrogen represents a second constraint to land treatment effluents and one which needs a greater research effort. Although secondary effluents generally contain rather modest concentrations of both NH_4^+-N and NO_3^--N, the application of large amounts of secondary effluent to soils,up to 7526 cm/ha/yr(120 inches/acre/year) in some engineering feasibility studies would result in rather large annual applications of nitrogen. Because of the environmental hazards associated with nitrate leaching, the proper management of land treatment systems, should be based on supplying only the amount of mineralized nitrogen removed by the growing crop or lost by biological denitrification. At the present time nitrogen balance estimates can be made (Walcott, 1972; Thomas et al, 1973) based on a rather incomplete understanding of the conditions occurring in a land treatment system. Improved data is needed to refine our nitrogen balance estimates for different cropping systems to assure adequate nitrogen renovation.

Survival of pathogens - All proposals for land application of secondary effluents include plans for prior disinfection of effluents to destroy pathogens yet doubts concerning the health hazards associated with land treatment of effluents remains a major issue limiting acceptance of this waste treatment alternative by portions of the scientific community, public health officials and the general public. These doubts probably arise because of a concern for the effectiveness of existing disinfection techniques (Foster and Engelbrecht, 1973), and the knowledge

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that effective day to day disinfection of effluents may be limited by human and mechanical failure. Methodology thus needs to be developed to improve the techniques utilized for disinfection supported by techniques for detecting low levels of pathogens (particularly viruses) in large volumes of effluent. Furthermore, if we do assume that at least some potential pathogens are still viable in secondary effluents transported to the treatment site, we must concern ourselves with the dispersion of pathogens in aerosols produced by spray irrigation; with the mechanisms by which pathogens survive or are eliminated from soil, plants and water; and with the movement of pathogens through the soil. We have very incomplete information relative to all these concerns.

Movement of inorganic ions - Heavy metals such as Ni, Cu, Pb, Zn, Hg, Cr, and Cd are often considered to be major long term constraints to land treatment of wastes. Since approximately two-thirds or more of the metals of the original sewage or industrial influents will occur in the treatment sludges rather than the effluents, the research needs in this area will be discussed in the "sludge"section.

There are a number of other inorganic wastewater constituents such as the cations Ca^{2+}, Mg^{2+}, K^{+}, Na^{+} and anions such as $SO_4^{=}$, $BO_3^{=}$, and Cl^{-} which will move through the soil filter with little renovation (See Section 3.6.6). Although none of these are considered highly toxic, their accumulation in ground or surface water supplies over a long period of time may result in an unacceptable increase in Total Disssolved Solids (TDS). Such increases might restrict the use of this water as a source of pottable water, or limit its industrial uses. Decisions must be made as to what level of TDS is acceptable after land treatment of effluents. Unacceptable levels of one or more of these constitutents must be identified so that land treatment is terminated or that steps are taken to remove or reduce the concentration of the undesirable constitutent. We have little information on what to base our decisions at the present time.

Organic compounds - Municipal and industrial waste effluents contain varying concentrations of a variety of organic compounds which are potential environmental toxins. Among the compounds frequently found are phenolic compounds, the chlorinated hydrocarbon pesticides and chlorinated biphenyls, detergent residues like ABS and NTA, petroleum products etc. The concentration of any one of these compounds which would reach the soil during land treatment of secondary effluent would probably be low. However, certain industries might be expected to have waste materials which would be totally unacceptable for application to soils without polluting ground or surface water supplies or destroying the existing vegetation. The groups of organic compounds which could be serious problems are chemically diverse and few generalizations on soil adsorption and micorbial degradation or detoxication in soil can be made at this time. Although these organic compounds can not normally be considered a major constraint to land treatment of effluent, continuing research must be conducted to insure that our ground and surface water supplies are not reduced in quality.

6.1.2. Liquid sludges

Many of the research needs discussed previously in the section on effluents apply equally as well to sludges. It should be remembered, that sludges contain many of these same constituents only in a more concentrated form. In addition, some individuals are still looking at land application of sludges as a method of ultimate disposal and are suggesting loading rates which could prove hazardous to ground and surface water quality.

Nitrogen transformations - Sewage sludges normally contain sufficient nitrogen to make them low analysis fertilizers, about one half of this nitrogen being in the organic form. Decisions on annual rates of application to land treatment systems should be based on a nitrogen balance which includes estimates of organic nitrogen mineralized, plant uptake and biological denitrification. A primary research need is to study the mineralization of organic nitrogen in the variety of sludges which can be expected to be applied to lands (anaerobically digested, activated sludge, alum and lime precipetated primary sludges, etc.). As with effluents, research must be conducted to provide improved estimates of biological denitrification in sludge treated soils. Since nitrogen transformations in soils are influenced greatly by the soil environment, we might expect rates of nitrogen mineralization, nitrification, and denitrification to be influenced by application and management techniques. No information is available to support or reject these assumptions.

Heavy metal reactions - Accumulation of heavy metals in soils is probably the most serious long term constraint to successful use of land for liquid waste treatment. To adequately design and manage land treatment systems we must have more reliable data in a number of areas. First, additional information must be obtained on the effects of heavy metals from wastes on yield, and the nutritional and product quality of crops. Second, considerable basic research must be done to better understand the soil biological and chemical reactions which influence the solubility, mobility, and plant uptake of heavy metals. Of particular significance is an improved understanding of the process of reversion. Third, at least some basic research effort should be expended to develop plants which are more resistant to heavy metal toxicities and/or exclude heavy metals.

Sludge Pathogens - All sewage sludges, unless disinfected or treated, still contain a relatively large population of indicator coliforms and pathogenic microorganism (Dean and Smith, 1973). It seems important therefore that studies be conducted which will evaluate the survivial of pathogens in soils from a variety of sludges e.g. anaerobically digested, lime and alum treated primary and secondary sludges, aerobically digested etc. As with effluents, the survival of viruses should receive the primary emphasis.

6.1.3 Septic tanks and other home sewage systems.

Problems associated with home sewage systems are most often associated with faulty installations (soils problems or poor construction) rather than an inherent problem in design. Therefore the research which needs to be done must develop the criteria and methodology necessary to determine what soils can accept wastes and which soils cannot be used. Alternate systems of waste treatment not involving land treatment must be developed for those areas where soils are unfit for conventional home sewage installations.

6.2. New studies required to define the problems remaining.

Considerable effort has been expended (see Proceedings of Joint Conference on *Recycling Municipal Sludges and Effluents on Land*, Champaign, Ill., July, 1973) and will continue to be expended (plans for a Ohio Basin workshop on *Recycling Urban Wastewater on Land*, in March, 1974) to delineate what research is needed for the successful utilization of land as an alternate system for treating wastes. This interest along with the research, demonstration, and monitoring effort already underway should result in the early solution of many of the problems discussed previously. Table 12 summarizes these study needs.

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Table 12. Studies Required to Define Existing Problems Associated With Land Treatment of Liquid Wastes in the Great Lakes Basin

A. Effluent 1. Basic research a) Studies of the fundamentals of biological denitrification. b) Studies on the transport of pathogens in spray aerosols. c) Studies of the scientific principles involved in the survival of enteric pathogens in soils with particular emphasis on viruses. d) Evaluate the mechanisms for the adsorption of potential organic concommitant detoxication by physical, chemical or biological mechanisms. e) Studies on the mechanism of movement of various inorganic ions through the soil matrix	2. Demonstration projects a) Projects to show the impact of the quantity of effluent on the growth & yield of a variety of plant cultivars on the fine to medium textured soils of the basin (include turf & forest) b) Projects to show the comparative effectiveness & management of overland flow (spray-irrigation) and sprinkler irrigation system for effluent renovation. These studies must accurately monitor ground and surface water quality parameters.	3. New Technology a) Improved methodologies to accurately measure potential hydraulic conductivity of soils. b) Methodology to effectively measure biological denitrification under field conditions. c) Improved & economical methods of effluent disinfection. d) Improved methodology for detecting low populations of pathogens.
B. Sewage Sludges 1. Basic research a) Studies on the rate and factors influencing organic N mineralization and biological denitrification in sludge treated soils. b) Studies to better understand the soil biological and chemical reactions which influence the solubility, mobility and plant uptake of heavy metals, particularly the process of reversion.	2. Demonstration projects a) Projects to show the impact of varying rates of sewage sludges on the growth and yield of a variety of plant cultivars.	3. New technology (See points b, c, and d under Section A_3)

Table 12. (cont) Studies Required to define Existing Problems Associated with Land Treatment of Liquid Wastes in the Great Lakes Basin

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c) Aquire information on the effects of heavy metals on the yield and nutrition of quality of crops raised on sludge treated soils. Food chain impact studies are of considerable importance.
d) Genetic studies on plant resistance to heavy metal toxicities & reduced adsorption of heavy metals
e) Studies on the factors influencing the survival of pathogens in sludge treated soils.

C. Individual home sewage systems

1. Basic Research	2. Demonstration projects	3. New technology
		a) Design alternative methods for small scale waste disposal systems. b) Improved technology evaluating soil capabilities for soil adsorption systems.

Section 7

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These references were chosen for inclusion because of their particularly broad and excellent coverage of one or more areas of liquid waste disposal on land. These references are also listed in the List of References Section which is an alphabetized lising of all references as used in the text.

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APPENDIX A
GREAT LAKES-UPPER MISSISSIPPI BOARD

ADDENDUM NO. 2
TO RECOMMENDED STANDARDS FOR SEWAGE WORKS
(1968 EDITION)

APRIL 1971

GROUND DISPOSAL OF WASTEWATERS

Interest has been expressed in the development of guidelines for engineering review of proposed projects for ground disposal of wastewaters.

There are apparently relatively few known large-scale installations of spray irrigation systems and very limited data available within the 10 GLUMRB states.

The protection of groundwater and surface resources is the major concern in the development of guidelines. However, quality of groundwater discharged to surface waters also must be considered the water quality criteria.

Practices must be established which will prevent wastes of any nature from being introduced into the fresh groundwaters which will so change their characteristics as to make them unsuitable for potable water supply or other present and future usage.

The priority of the water usage is subject to the jurisdiction of the appropriate state and local regulatory agencies.

Preliminary Considerations

Ground disposal installations are normally used where the waste contains pollutants which can successfully be removed through distribution to the soil mantle. These pollutants can be removed through organic decomposition in the vegetation-soil complex and by adsorptive, physical, and chemical reactions with earth materials. Preliminary considerations of a site for ground disposal should be the compatibility of the waste with the organic and earth materials and the percolation rates and exchange capacity of the soils. The ground disposal of wastewater will eventually recharge the local groundwater; therefore, the quality, direction and rate of movement and local use of the groundwater, present and potential, are prime considerations in evaluating a proposed site.

It is essential to maintain an aerated zone of at least five feet and preferably more, to provide good vegetation growth conditions and removal of nutrients. It must be realized a groundwater mount will develop below after it is in use. The major factors in design of ground disposal fields are topography, soils, geology, hydrology, weather, agricultural practice, adjacent land use and equipment selection and installation.

Design Report

The design report shall include maps and diagrams as noted below. It shall also include any additional material that is pertinent about the location, geology, topography, hydrology, soils, areas for future expansion and adjacent land use.

Location

(1) A copy of the U.S.G.S. topographic map of the area (7½-minute series where published) showing the exact boundaries of the spray field.

(2) A topographic map of the total area owned by the applicant at a scale of approximately one inch to 50 feet. It should show all buildings, the waste disposal system, the spray field boundaries and buffer zone. An additional map should show the spray field topography in detail with a contour interval of two feet, and include buildings and land use on adjacent lands within ¼ mile of the project boundary.

(3) All water supply wells which might be affected shall be located and identified as to uses; e.g., potable, industrial, agricultural, and class of ownership; e.g., public, private, etc.

(4) All abandoned wells, shafts, etc., shall be located and identified. Pertinent information thereon shall be furnished.

Geology

(1) The geologic formations (name) and the rock types at the site.

(2) The degree of weathering of the bedrock.

(3) The local bedrock structure including the presence of faults, fractures and joints.

(4) The character and thickness of the surficial deposits (residual soils and glacial deposit).

(5) In limestone terrain, additional information about solution openings and sinkholes is required.

(6) The source of the above information must be indicated.

Hydrology

(1) The depth to seasonal high water table (perched and/or regional) must be given, including an indication of seasonal variations. Static water levels must be determined at each depth for each aquifer in the depth under concern. Critical slope evaluation must be given to any differences in such levels.

(2) The direction of groundwater movement and the point(s) of discharge must be shown on one of the attached maps.

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(3) Chemical analyses indicating the quality of groundwater at the site must be included.

(4) Indicate the source of the above data.

(5) The following information shall be provided from existing wells and from such test wells as may be necessary:

(a) Construction details--where available: Depth, well log, pump capacity, static levels, pumping water levels, casing, grout material and such other information as may be pertinent.

(b) Groundwater quality: e.g., nitrates, total nitrogen, chlorides, sulphates, pH, alkalinities, total hardness, coliform bacteria, etc.

(6) A minimum of one (1) groundwater monitoring well must be drilled in each dominant direction of groundwater movement and between the project site and public well(s) and/or high capacity private wells with provision for sampling at the surface of the water table and at five (5) feet below the water table at each monitoring site. The location and construction of the monitoring well(s) must be approved. These may include one or more of the test wells where appropriate.

Soils

(1) A soils map should be furnished of the spray field, indicating the various soil types. This may be included on the large-scale topographic map. Soils information can normally be secured through the USDA Soil Conservation Service.

(2) The soils should be named and their texture described.

(3) Slopes and agricultural practice on the spray field are closely related. Slopes on cultivated fields should be limited to 4% or less.
Slopes on sodded fields should be limited to 8% or less. Forested slopes should be limited to 8% for year-round operation, but some seasonal operation slopes up to 14% may be acceptable.

(4) The thickness of soils should be indicated. Indicate how determined.

(5) Data should be furnished on the exchange capacity of the soils. In case of industrial wastes particularly, this information must be related to special characteristics of the wastes.

(6) Information must be furnished on the internal and surface drainage characteristics of the soil materials.

(7) Proposed application rates should take into consideration the drainage and permeability of the soils, the discharge

capacity, and the distance to the water table.

Agricultural Practice

(1) The present and intended soil-crop management practices, including forestation, shall be stated.

(2) Pertinent information shall be furnished on existing drainage systems.

(3) When cultivated crops are anticipated, the kinds used and the harvesting frequency should be given; the ultimate use of the crop should also be given.

Adjacent Land Use

(1) Present and anticipated use of the adjoining lands must be indicated. This information can be provided on one of the maps and may be supplemented with notes.

(2) The plan shall show existing and proposed screens, barriers, or buffer zones to prevent blowing spray from entering adjacent land areas.

(3) If expansion of the facility is anticipated, the lands which are likely to be used for expanded spray fields must be shown on the map.

Treatment Before Land Disposal

In general, the equivalent of secondary treatment will be required. All wastes must be amendable to treatment by the soil prior to application. All wastes to be spray irrigated shall be disinfected. Disinfection may be required for other types of irrigation. Screening shall be provided in all cases where solids are expected of a size equal to or greater than the nozzle hole diameter.

Storage shall be provided to the maximum capacity required to accommodate flows in excess of quantities to be irrigated.

Piping to Sprinklers

The piping should be so arranged to allow the irrigation pattern to be varied easily. Stationary systems are preferred; but if a moveable system is proposed, one main header must be provided with individual connections for each field and sufficient spare equipment must be available to assure noninterrupted irrigation. Facilities must be provided to allow the pipes to be completely drained at suitable points to prevent pollution and freezing.

Sprinkling System

Sprinklers must be so located as to give a nonirrigated buffer zone around the irrigated area and design of the buffer zone must consider wind transport of the wastewaters. The system shall be designed to provide an even distribution over the entire field.

The application rate must be selected low enough to allow the waters to percolate into the soil and to assure proper residency

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within the soil mantle. Proposed application rates will not be accepted without substantiating data.

In general, sufficient monitoring controls should be provided to indicate the degree of efficiency with which the sprinklers are working. A pressure gauge and flow meter should be provided.

Runoff

The system shall be designed to prevent surface runoff from entering or leaving the project site.

Fencing

The project area shall be enclosed with a suitable fence to preclude livestock and discourage trespassing. A vehicle access gate of sufficient width to accommodate mowing equipment should be provided. All access gates should be provided with locks.

Warning Signs

Appropriate signs should be provided along the fence around the project boundaries to designate the nature of the facility and advise against trespassing.

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Land Use/Water Quality Relationships in the U. S. Great Lakes Basin
Task A: To assess problems, management of programs and research...
Category A14 - Solid Waste Disposal

SOLID WASTE DISPOSAL AREAS

prepared by
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GREAT LAKES BASIN COMMISSION
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To be used as portion of the U. S. Task A Report on GREAT LAKES POLLUTION FROM LAND USE ACTIVITIES by the International Joint Commission - prepared in partial fulfillment of U. S. Environmental Protection Agency Contract No. 68-01-1598

August 1974

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PREFACE

The authors wish to point out that the term "sanitary landfill" means different things to different people. The U. S. EPA prefers to reserve the term "sanitary landfill" for a controlled landfill operation where pollution abatement measures are in effect. Uncontrolled facilities are preferably called "dumps" or "cosmetic landfills".

These definitions are generally adhered to in this report, however, in some of the literature quoted this convention is not observed.

Section 1

SUMMARY

1.1 Introduction

Pollution of Great Lakes waters by solid waste disposal areas is presently a problem and can become a more serious problem in the future. With the increase in urban development in the basin, the resulting waste to be disposed of will also increase. Moreover, landfills are becoming increasingly popular as a means for such disposal. The objective of this report is to assess the present pollution hazard as well as the potential for future pollution. In addition, the technological and legislative aspects of pollution control are reviewed.

1.2 Summary of Findings and Conclusions

(1) access to the literature in this field is quite good due to extensive annotated bibliographies

(2) contamination of Great Lakes waters can occur by three indirect mechanisms: flow of polluted groundwater, flow of landfill gases, and airborne transport

(3) mathematical models for quantifying transport are currently under development and should be available in the near future

(4) only limited data are available from monitoring of pollutant transport around landfills

(5) the regional potential for pollution in the Great Lakes basin can be evaluated semiquantitatively based on regional geology and regional climatic data such as rainfall and wind

(6) natural renovation mechanisms simply delay pollution transport and should not be relied upon; pollutants should be intercepted at the landfill

(7) data on existing landfills in the Great Lakes basin exist but, in general, are not readily available

(8) all states in the Great Lakes basin have legislation and enforcement agencies to regulate landfill operations

(9) there are active ongoing research programs relating to these pollution problems

(10) research programs at the prototype level and demonstration programs are needed to validate models for pollution transport

(11) determination of regional groundwater levels and flowrates would facilitate predicting pollutant movement

(12) the principles outlined in section 3.5 should be applied to developing regional land use maps to delineate acceptable and unacceptable areas for landfill sites

(13) political and legal aspects of implementing technology may be complicated; the economics of pollution control may appear unfavorable because little or no capital has been previously invested in these activities

Section 2

SUPPORTING MATERIAL

2.1 Introduction

The present study was conducted by Drs. Moore, Sykes and Stiefel of the Department of Civil Engineering, The Ohio State University, during the period December, 1973 through July, 1974.

The nature of the problem was clearly defined in the original task statement and, because sanitary landfills are easily defined geographically, they may be considered as point sources of pollution rather than as diffuse sources. The approach to the study was to (1) define the distribution of sanitary landfills within the basin, (2) determine mechanisms for indirect pollution transport, and (3) delineate other regional parameters such as surface water flow and wind that contribute to indirect transport.

2.2 Scope of Study

To determine this information, the literature was reviewed and numerous personal contacts were made.

2.3 Study Procedure

Extensive use was made of the following abstracts in reviewing the literature:

(1) Sanitary Landfill Bibliography, R. C. Steiner and Renee Kantz, 1968 covering 1925 through 1968

(2) Solid Waste Management, Abstracts from the Literature, U S E P A, for 1964 through 1968

(3) Refuse collection and disposal, An Annotated Bibliography, U.S. Department of Health, Education, and Welfare, PHS, 1956-57 and 1962-63

(4) Solid Waste Management: Abstracts and Excerpts from the Literature, U.S. Department of Health, Education, and Welfare, PHS, 1970,

Based on a review of some 225 pertinent papers, mechanisms and incidents of pollution which applied directly or indirectly to the Great Lakes basin were summarized.

In addition regional data pertinent to indirect transport mechanisms were obtained from the following sources:

(1) Great Lakes Basin Commission, Great Lakes Basin Framework Study, Appendix No. 3, 1971

(2) Introduction to Hydrology, Viessman, Harbaugh, and Knapp, 1972

Finally, distribution of landfill sites in the Great Lakes basin was summarized based oh response from state agencies. The responses received were as follows:

(1) Illinois - responded with approximate locations

(2) Indiana - responded with approximate locations

(3) Michigan - responded but locations exist only in unsummarized card file

(4) Minnesota - no response

(5) New York - responded with approximate locations

(6) Ohio - responded with approximate locations

(7) Pennsylvania - responded with approximate locations

(8) Wisconsin - responded with approximate locations

Information on ongoing research was provided by the US EPA.

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Section 3

REVIEW OF FINDINGS OF PREVIOUS STUDIES

3.1 General Description of Land Use Category

Contamination of near shore lake waters by landfills will, by definition, result from indirect processes. The carriers of contaminants will be water or air. For water to act as a carrier, it must first become contaminated by the landfill and it then must reach lake waters. The contamination processes may be:

(1) contamination by surface water flowing through or from landfills,

(2) contamination of water percolating through the landfill and subsequently infiltrating into the groundwater regime,

(3) groundwater flowing through landfills, and

(4) gases from landfills dissolving in groundwater.

Once water has become contaminated it may enter the lake waters by any of the following processes;

(1) direct flow of surface water into the lake,

(2) direct flow of groundwater into the lake, or

(3) simple or complex flows involving contaminated waters leaving the groundwater regime and becoming surface flow or vice versa.

For air to act as a carrier of contaminants into the lake waters, it must first incorporate landfill decomposition gases and it then must contact and dissolve in the lake waters. Landfill decomposition gases are principally methane and carbon dioxide. These gases may either move through the soil surrounding the landfill or leave the soil around or over the landfill and enter the atmosphere. Solution of these gases in lake waters may occur either by bubbling if the gas enters underwater, or by diffusion through the lake water surface. As with transport processes involving water, transport by air may also involve complex, multi-step mechanisms.

3.2 Length of Time Activities in Practice

Disposal of solid waste by landfilling is a very old procedure. More

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important, however, is the exponential rate at which the practice of this disposal method has increased. Furthermore, there are indications that the popularity of the method will continue to increase.

3.3 Types and Nature of Pollutants Associated with Landfill

Pollutants from landfills may be either liquid or gaseous. The liquid constituents consist of a variety of extremely diverse inorganic and organic compounds. For a review of this subject the reader is referred to Reference 13.

The gaseous constituents consist primarily of carbon dioxide and methane. Methane forms an explosive mixture when introduced in small amounts in air and, therefore, constitutes a hazardous pollutant.

3.4 State-of-the-art in Assessing and Quantifying Problems

The quantification of these problems can be said to be within the state-of-the-art but highly involved and very costly. Current research projects should result in practical models for the prediction of liquid and gas movements around landfills. However, monitoring of existing landfills in a variety of areas will be required to verify the models properly.

3.5 Mobility of Pollutants within the System

3.5.1 Contamination of Groundwater

The qualitative aspects of contamination of groundwater by leaching from landfills are presented by Engineering-Science Inc. (1961) in California State Water Pollution Control Board Publication No. 24. In brief, their conclusions were that contaminants are introduced into the groundwater by infiltration and percolation, refuse decomposition, gas production and movement, leaching, and groundwater flow. Leaching is strongly influenced by the amount of surface infiltration which in turn is affected by the rate of rainfall or water application, the type of cover on the landfill, and climatic conditions. The authors point out that transmission of water through the aquifer may be retarded by the high moisture-retaining capacity of landfill materials and by evaporation caused by elevated landfill temperatures.

They continue, pointing out that refuse contains abundant inorganic and organic substances which can potentially pollute groundwater. Decomposition processes involving the organic constituents produce large quantities of methane and carbon dioxide gas. The carbon dioxide is particularly harmful in that it dissolves calcium, magnesium and iron which may accumulate excessively in the groundwater. It is noted that gases may be vented by using permeable landfill covers, however, this is counterproductive to retarding infiltration.

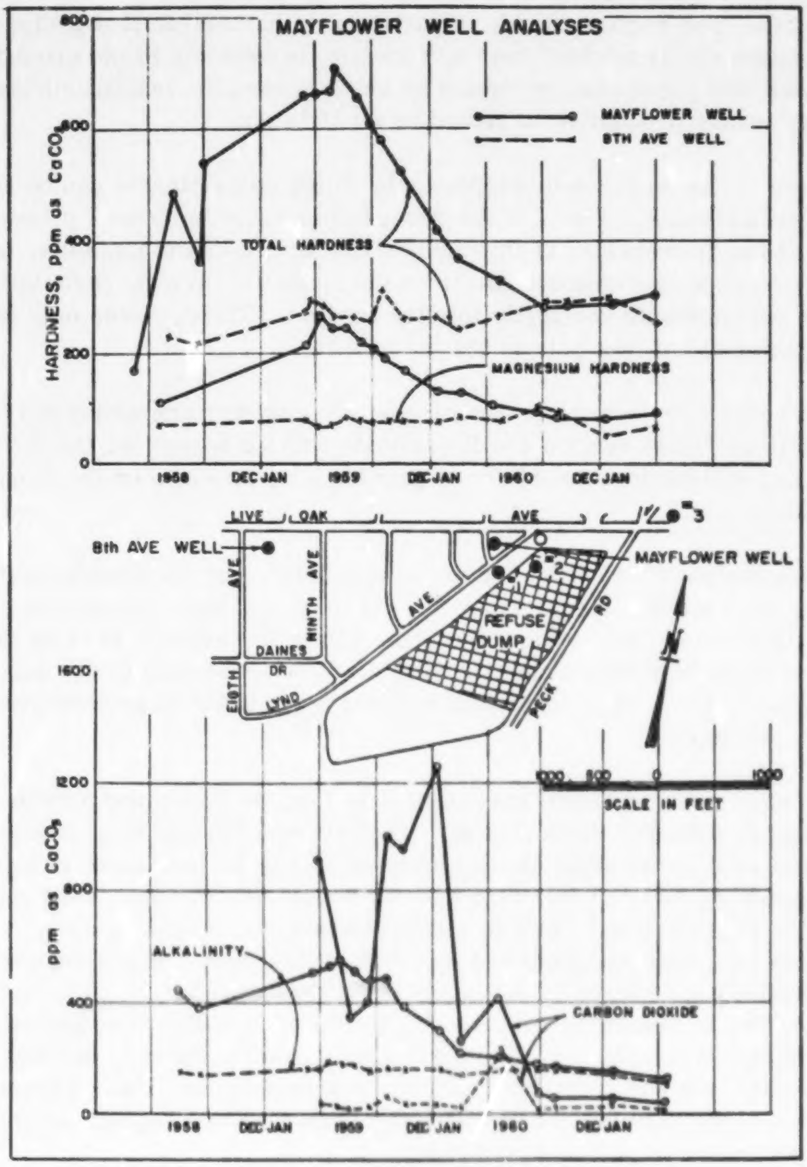
The authors delineate three mechanisms by which contaminants can be transferred into the groundwater. First, if the groundwater table is above the base of the landfill and if the groundwater is flowing horizontally, contaminants may be leached into the groundwater downstream from the landfill. Second, percolating water can leach contaminants vertically into the landfill. Third, gases may leave the landfill and contact and thus pollute the groundwater.

Several research projects have documented groundwater contamination by leaching in landfills. While section 4 will delineate related research, the details of certain projects will be described here to provide a perspective on the magnitude of the problem.

Engineering-Science Inc. (1961) reported alkalinity, carbon dioxide as calcium carbonate, total hardness, chloride, and pH from well data adjacent to a refuse dump in Monrovia, California. The plan, shown in figure 1, is of an area having a predominantly southwesterly groundwater flow. A portion of the data are shown on the same figure. They indicate a marked degradation of groundwater quality near the refuse dump.

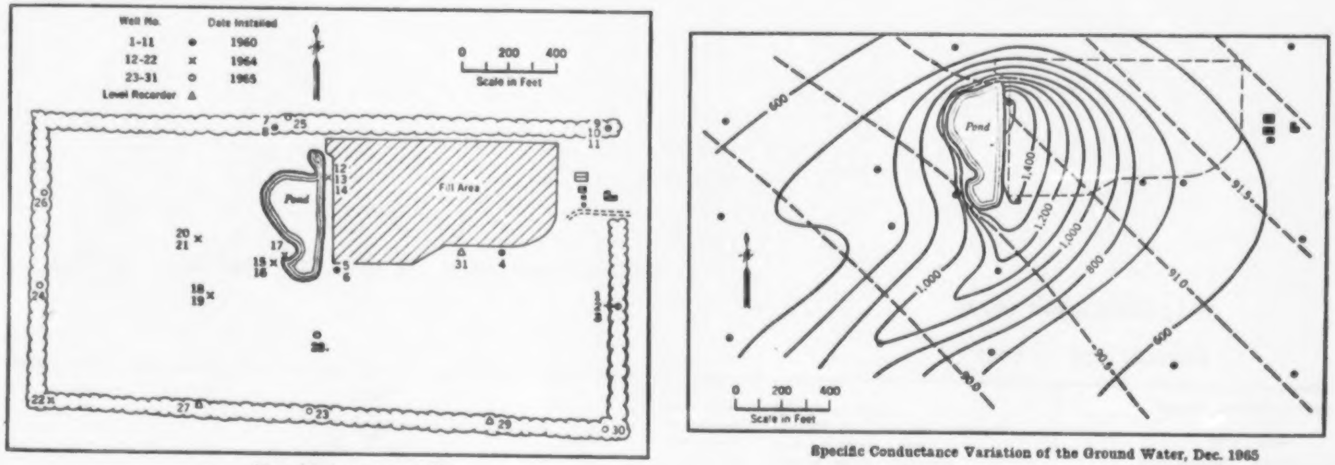
Andersen and Dornbush (1967) presented data from wells around a refuse disposal site near Brookings, South Dakota. The site was located in an inactive gravel excavation area. The areal geology showed a 12 to 30 inch layer of sandy loam or loam overlying 12 to 31 feet (3.6 to 9.4 meters) of outwash. The groundwater flow, as shown in figure 2, was in a southwesterly direction, and the groundwater table was approximately 6.5 feet (2 meters) below the ground surface. Soil permeabilities ranged from 1 foot/day (.3 meters/day) to 2000 feet/day (610 meters/day) due to lensing of soil types. A total of 22 wells were placed and water was analyzed for pH, specific conductance, total hardness, calcium hardness, alkalinity, chloride, nitrate, sodium, potassium, and iron. Figure 2 shows a portion of the data taken 5.5 years after dumping was begun. Again impairment of groundwater quality is apparent.

Merz (1954) reported the results of a study of a landfill near Riverside, California. The dump, initially opened in the early 1920's, was located in an area composed of sand and gravel having a 3 to 6 foot (.9 to 1.8 meter) layer of clay approximately 30 feet (9.1 meters) below the ground surface. The groundwater table was located at or slightly above the base of the dump and flowed in a southwesterly direction. The site plan, locating some 36 wells and wellpoints, is shown in figure 3. Groundwater was analyzed for pH, carbon dioxide, total



(from reference 3)

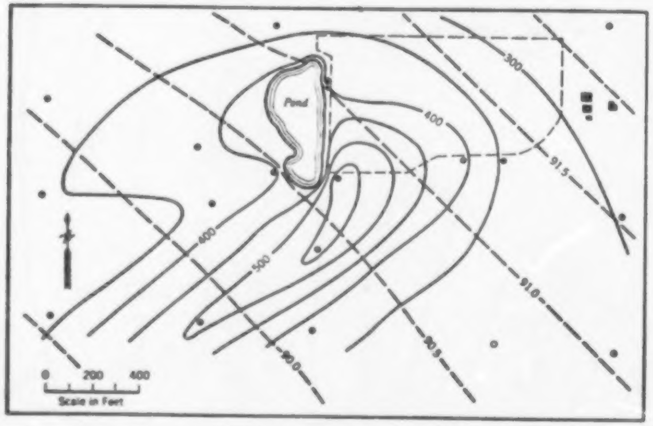
Fig. 1- Site plan and data for Monrovia landfill.



Map of Refuse Disposal Site

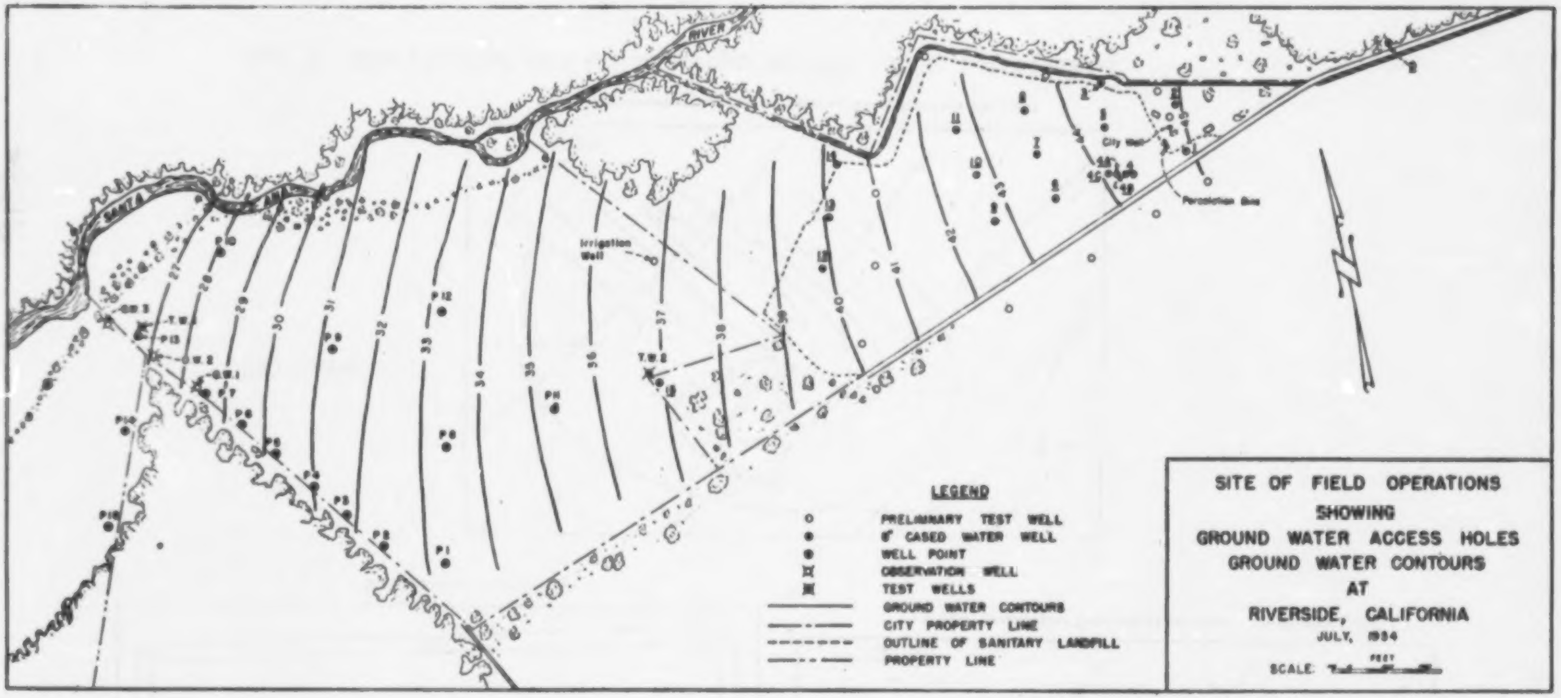
Specific Conductance Variation of the Ground Water, Dec. 1965

1 foot = .305 meters



Isoconcentrational Lines of Ground Water Hardness, Dec. 1965

Fig. 2 - Site plan and data for Brookings landfill. (from reference 1)



1 foot = .305 meters

(from reference 7)

Fig. 3 - Site plan and data for Riverside landfill.

hardness, alkalinity, calcium, magnesium, sodium, potassium, total iron, ferrous iron, chloride, sulfate, inorganic phosphate, organic nitrogen, ammonia nitrogen, and BOD. Table 1 presents average data for 1952-54 (approximately 30 years after initiation of dumping) for two typical control wells and two typical downstream wells. Again, impairment of groundwater quality is apparent.

3.5.2 Migration of Gases

A second indirect method for contamination of lake water by landfill is by movement of landfill gas. Three types of movements must be considered. First, as discussed in section 3.1, gas can move into contact with and contaminate the groundwater. Second, gas can move through the ground surrounding the landfill and exit into lake waters or surface waters which flow into the lake. Third, gas can move into the atmosphere and be blown over the lakes or surface waters which flow into the lakes.

Movement of gases through soil occurs due to pressure flow and diffusion flow. Pressure flow results in a net component of gas movement in the direction of decreasing pressure. Diffusion flow occurs because of gradients of gas concentrations. In mixed gas systems, each individual gas flows under its own concentration gradient. Thus the various gases may experience flows in different directions. Consider a simple case of a landfill gas composed of methane and carbon dioxide flowing into an ambient gas composed of nitrogen and oxygen. All four gases will have a net component of flow away from the landfill due to the total pressure gradient caused by the generation of gas in the landfill. Methane and carbon dioxide will diffuse away from the landfill because of concentration gradients. Conversely, nitrogen and oxygen will diffuse toward the landfill due to their concentration gradients. Both pressure flow and diffusion flow will force methane and carbon dioxide (landfill contaminants) away from the landfill.

As the landfill gas moves through the soil surrounding the landfill, it may be adsorbed onto the soil particles. Carbon dioxide is particularly susceptible to adsorption and may react with the soils thereby liberating calcium, magnesium, or iron.

Several research projects have documented gas movements around sanitary landfills. While section 4 will delineate related research, the details of certain projects will be described here to provide a perspective on the magnitude of the problem.

In the project described in section 3.5.1, Engineering-Science Inc. (1961) presented the results of gas composition measurements in test holes 1, 2 and 3 as shown in figure 1. These data are presented in Table 2. Relative to hole 3, holes 1 and 2 show enrichment in carbon dioxide and methane and depletion in oxygen and nitrogen.

Table 1

COMPARISON OF UPSTREAM AND DOWNSTREAM GROUND WATERS

Determination	Upstream or Native Waters		Downstream Waters					
			Test Well No. 2			Test Well No. 1		
	Well 0	City Well	Top 12′ Depth	Highest Conc. 30′ Depth	Bottom 62′ Depth	Top 20′ Depth	Highest Conc. 35′ Depth	Bottom 95′ Depth
Total Hardness	297	331	575	752	288	255	316	283
Alkalinity	280	316	502	768	253	208	265	191
Calcium	91	80	173	212	85	75	92	72
Magnesium	15	12	41	52	15	14	20	13
Sodium	73	44	182	212	62	46	57	40
Potassium	4.2	3.5	12	12	5.6	5.1	5.5	3.8
Chloride	60	48	220	267	72	47	64	30
Sulfate	60	42	54	top	50	62	75	61

(from reference 7)

Table 2

Results of Mayflower Test Hole

Gas

	Percent by Volume			
	CO_2	CH_4	O_2	N_2
Test Hole No. 1				
Dept, ft: 20	28.6	17.6	1.8	52.0
40	26.2	12.9	2.8	58.1
60	29.8	10.6	1.2	58.4
80	32.2	14.0	1.1	52.7
100	12.6	6.5	14.8	66.1
Test Hole No. 2				
Depth, ft: 20	43.5	44.9	1.7	9.9
60	31.4	14.7	3.8	50.2
80	45.3	21.9	1.9	30.9
96	40.8	22.2	2.7	34.3
Test Hole No. 3				
Depth, ft: 20	0.03	0.0	21.5	78.5
40	9.5	0.0	9.7	80.8
60	15.4	0.0	6.4	78.2
80	17.0	0.2	4.1	78.7
96	23.7	1.3	1.5	73.5

1 foot = .305 meters
(from reference 3)

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Bishop et. al. (1965) describe gas data in a test landfill at the Azusa Rock and Sand Co. in the San Gabriel Valley in Los Angeles County, California. The site was less than one acre and the fill varied from 18 to 25 feet (5.5 to 7.6 meters) in three 6 to 7 feet (1.8 to 2.1 meters) lifts placed in March, 1962. Fifty seven gas collection probes and wells were installed in and around the landfill. Figure 4 shows gas compositions at the bottom of the test fill and relative concentrations of carbon dioxide in the test fill and in the surrounding soil. Enrichment of carbon dioxide was apparent in the surrounding soil.

Engineering-Science, Inc. (1967) describe research on gas flow around a sanitary landfill at an unnamed community in California. Carbon dioxide, methane, oxygen, and hydrogen gas concentrations were measured. Figure 5 presents the results for methane concentration. Enrichment of methane in the surrounding soil is apparent.

Movement of gas into the atmosphere can occur by transport through the cover of the landfill or by transport upward through soils surrounding the landfill. The same principles of movement govern this flow as govern movement of gases within the soil. The quantity of gas moving upward into the atmosphere relative to the quantity remaining in the soil and/or being adsorbed into the groundwater depends on the effective permeability ratios of the various soils involved. Research in this area is limited. However Bishop et. al. (1965) estimate that a high percentage of gas moves into the atmosphere.

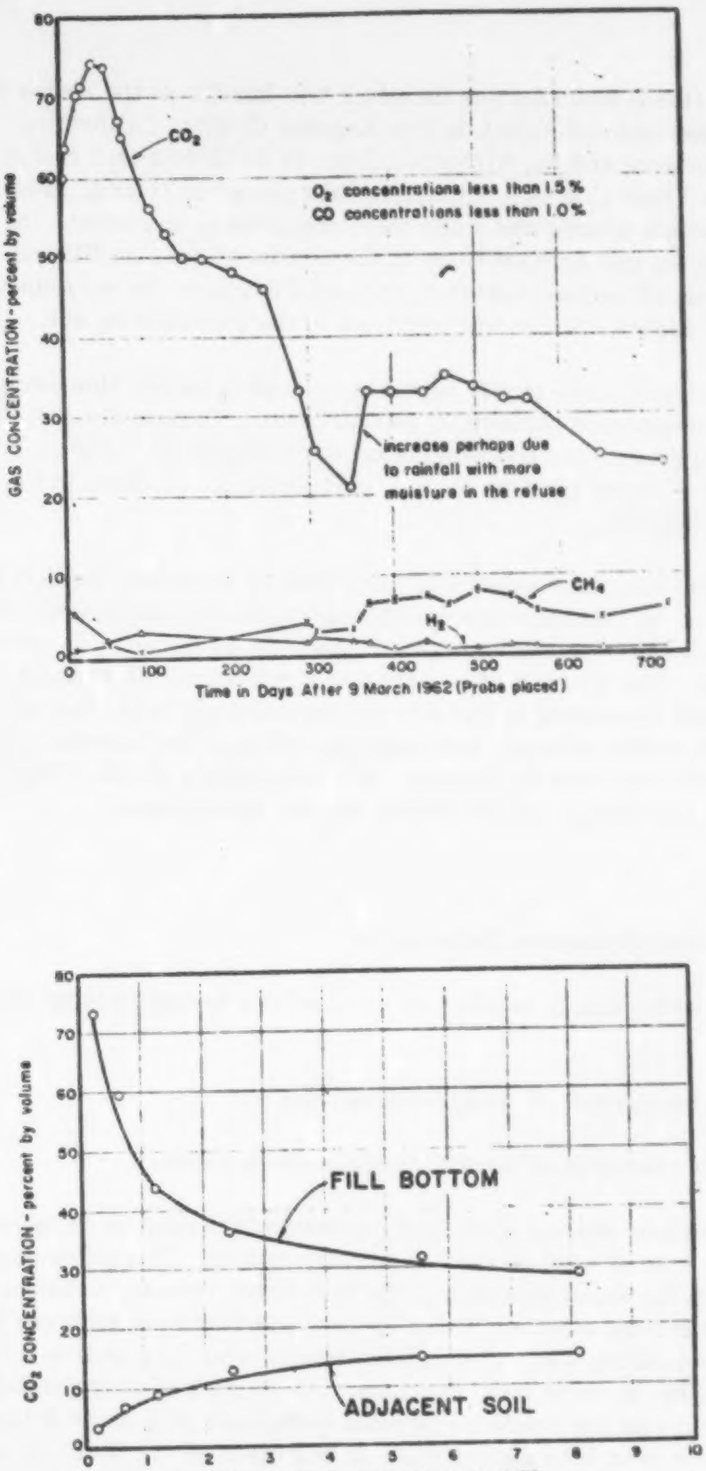
3.5.3 Airborne Transport Mechanisms

Transport of contaminants to lakes by air can be accomplished by two mechanisms:

(1) direct transport of landfill debris, and

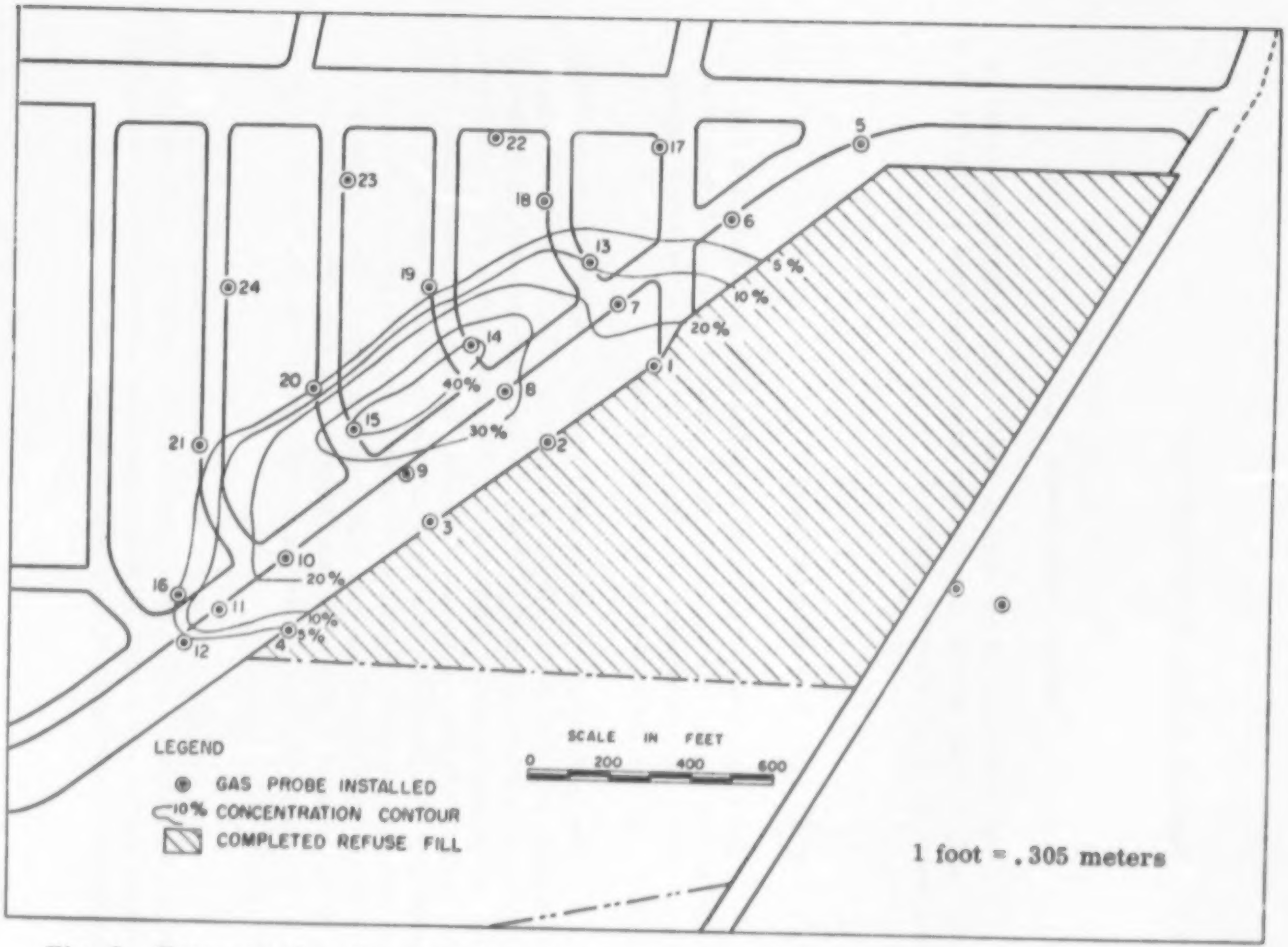
(2) direct transport of landfill decomposition gases.

Both of these mechanisms depend upon wind patterns which may be quite complex. This is particularly true of wind patterns near lake shores. The difference in temperature between the warm ground and the cool water results in thermal convective winds of a localized nature. These local winds may have patterns very different from the prevailing winds. Landfills located near lake shores will be particularly susceptible to these local patterns. At the risk of oversimplification, it may be stated that the existence of local turbulence will make it highly probable that landfills near lake shores will, at least part of the time, be subjected to winds which will move contaminants toward the lake. This is true even if the prevailing winds are blowing off of the lakes.



(from reference 2)

373< Fig. 4 - Data from Azusa landfill.



1 foot = .305 meters

Fig. 5 - Presence of methane gas beneath a community adjoining a landfill. (from reference 4)

For any given landfill site, a rational assessment of the potential for wind transported contamination may be obtained by measuring wind duration, intensity, and direction as a function of time. Standard techniques for such studies exist.

3.5.4 Regional Aspects of Contamination

3.5.4.1 Surface Water Basin

The delineation of the surface water basin of the Great Lakes is easily done, and, in fact, serves to define the Great Lakes Basin. The limits of the surface water basin are shown in figure 6.

3.5.4.2 Groundwater Basin

The groundwater basin may be defined as the outer limits of groundwater having a total potentiometric head gradient such that it may flow into the lakes either as groundwater or after joining the surface water regime of the basin through the process of groundwater runoff.

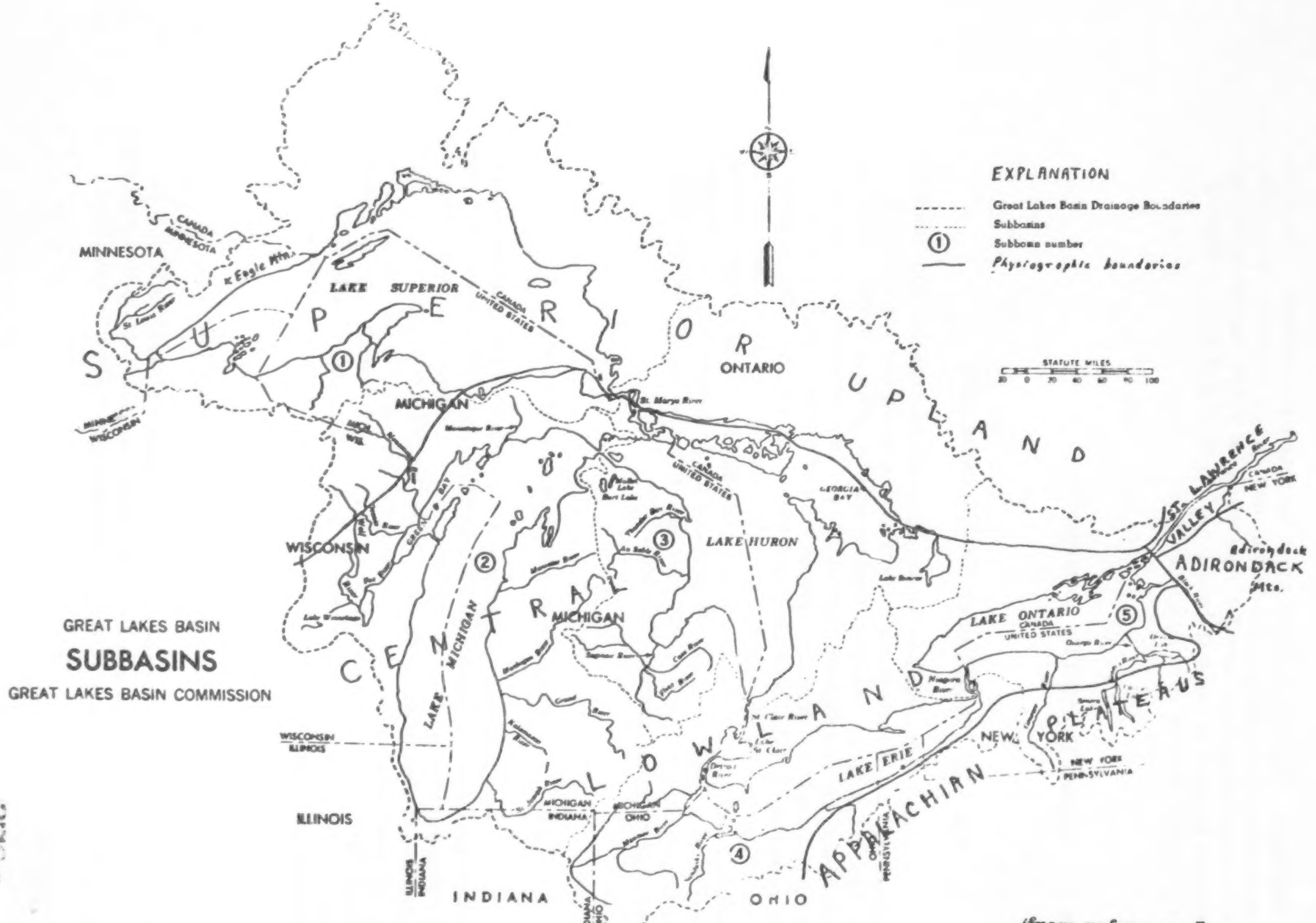
The groundwater basin is much easier to define than to delineate. While the surface water basin is defined by topographic features which change only within the framework of geologic time, the groundwater basin is defined by the maximum regional potentiometric head. This maximum head may fluctuate over short periods of time. Indeed, within significantly short time spans a regional potentiometric maximum may be supplanted by another maximum at a relatively remote geographic location. Moreover, because in any given geographic location there may be several independent aquifers, the potentiometric maxima for the several aquifers are not likely to coincide. The problem of defining the groundwater basin is further complicated if pumping or recharge wells are operating.

As a first approximation, the groundwater basin may be taken to coincide with the surface water basin. However, the reader is cautioned that this may introduce significant errors. These errors may become critical in regions where the surface water basin is very near to the lakes.

3.5.4.3 Wind

As discussed in section 3.5.3, wind patterns are highly dependent

375<



Base by Great Lakes Basin Commission

(from reference 7)

Physiography after Fenneman, 1946

Fig. 6 - Great Lakes Basin showing drainage system and physiographic regions.

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on local conditions. This is particularly true for near shore regions. Thus it is not practical to attempt to define regional potential for contamination due to wind transported contaminants from landfills other than to reiterate the statement that local turbulence is likely to result in landfill-to-lake transport at least some of the time for landfills located close to lake shores.

3.5.5 Regional Potential for Contamination

3.5.5.1 Hydrogeology of Great Lakes Basin

Possible mechanisms for transport of contaminants from landfills to near shore lake waters are strongly controlled by geological aspects of the regions. Moreover, these geological aspects may be highly localized. Thus any attempt to assess the potential for contamination of lake waters by landfills on a regional basis must be prefaced by a strong word of caution. There may be perfectly acceptable landfill sites within potentially bad regions. This is particularly true if the landfill is properly operated. Conversely, local conditions or poor operation management may result in a given landfill posing a serious threat to the lake water in regions having low potential for contamination. Nevertheless, certain regional considerations can be presented to assist in planning and siting landfills to minimize contamination hazards.

3.5.5.2 Contamination by Surface Water Runoff

Perhaps the most dangerous pollution mechanism involves surface water which flows from or through landfills and then flows into a lake. Such water is highly contaminated and has little opportunity for purification through biodegradation, dilution, or adsorption processes. While landfills located adjacent to lakes pose the most serious hazard, those located near streams flowing into the lakes also have a high contamination potential. The closer the landfill is to the mouth of the stream the more serious the hazard. Fortunately, these potentially serious situations are quite apparent and control by legislation is a viable option.

3.5.5.3 Contamination by Polluted Groundwater

Mechanisms for pollution of groundwater by landfills have been discussed in Section 3.1. In order to contaminate the lakes, this polluted groundwater must flow into the lakes directly or into streams which flow into lakes.

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The importance of regional geology in this process was discussed in section 3.5.4.2 in general terms. The present section, which draws heavily on the Great Lakes Basin Framework Study, Appendix No. 3, Geology and Groundwater (Great Lakes Basin Commission, 1971), delineates particular aspects of the hydrogeology of the basin pertinent to the present problem.

The Great Lakes basin is underlain by a structural basin of sedimentary rocks which becomes a structural platform extending to the east (see figure 7). Crystalline rocks outcrop in the eastern and western regions of the basin. The bedrock is mantled by glacial materials and alluvium derived therefrom (see figure 8). The galcial deposits consist of unstratified drift (till) and stratified drift (sand and gravel outwash and glacial lake deposits). Particularly significant to the present problem are the following observations:

(1) Because the Great Lakes have occupied basins in the geologic past larger than they presently occupy, fine grained glacial lake deposits compose much of the shoreline of the lakes.

The implication of this is that the soils on the shores of the lakes will frequently have low permeabilities because of the fine grained nature of the glacial lake deposits. These deposits are delineated on a broad scale in figure 8 and the reader is referred to figures 3-8, 3-10, 3-14, 3-17, 3-21, 3-24, 3-31, 3-36, 3-41, 3-43, 3-47, 3-50, 3-54, 3-56, and 3-58 in Great Lakes Basin Commission (1971) for more detailed maps. Reference to these figures shows the following areas to be not covered by glacial lake deposits:

(1) the western tip of Lake Superior

(2) the western shore of Lake Michigan south and east of Green Bay

(3) parts of the east shore of Lake Michigan

(4) the southwest shore of Lake Erie

(5) parts of the east tip of Lake Erie

(6) several other highly localized areas.

Though the above listed areas may represent exceptions, in general the soils which compose the margins of the Great Lakes may be expected to be relatively impermeable and act as natural barriers to protect the lakes from direct inflow of groundwater.

(2) Alluvium derived largely from reworked glacial drift lies in the valleys of many streams.

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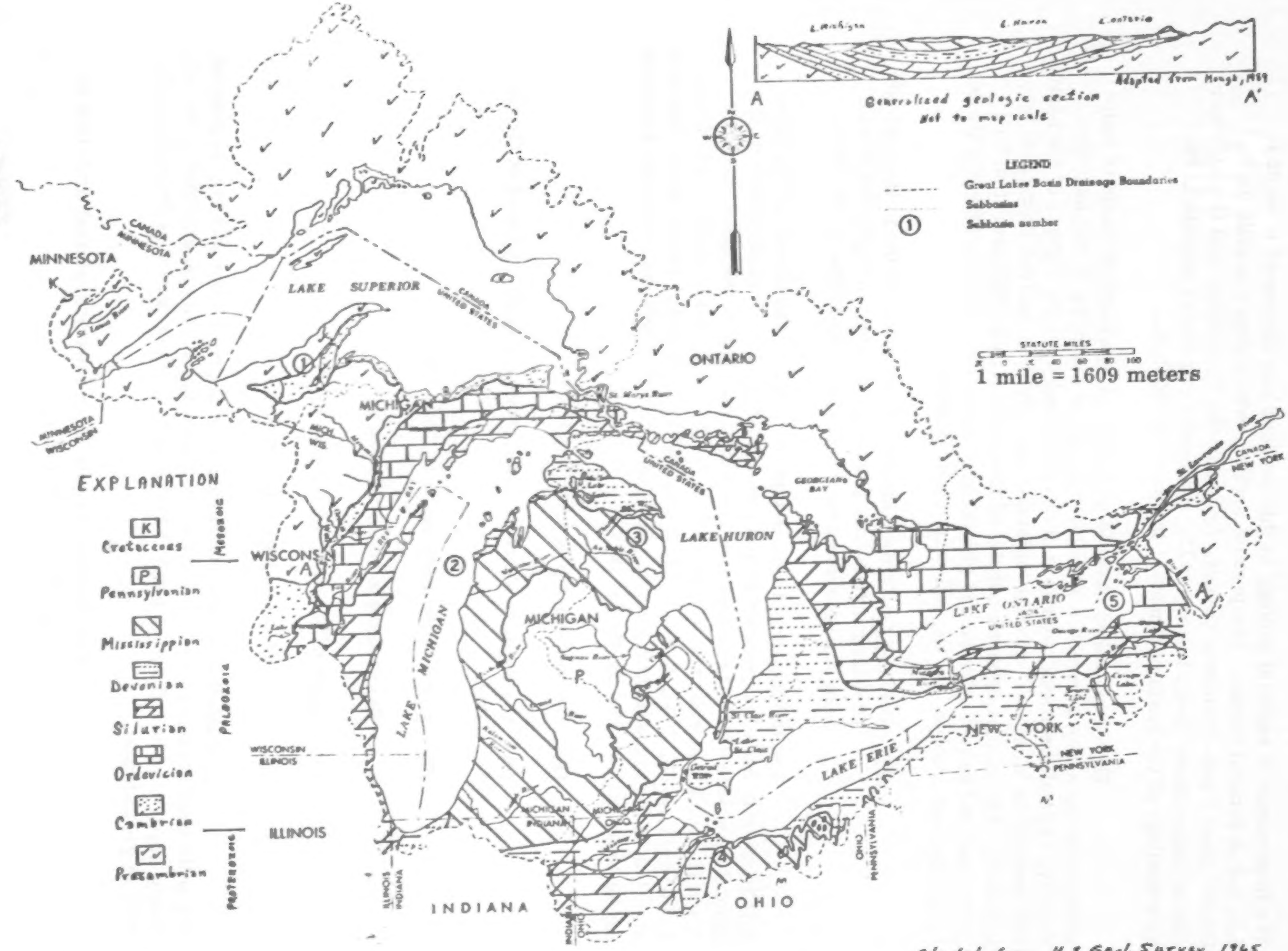


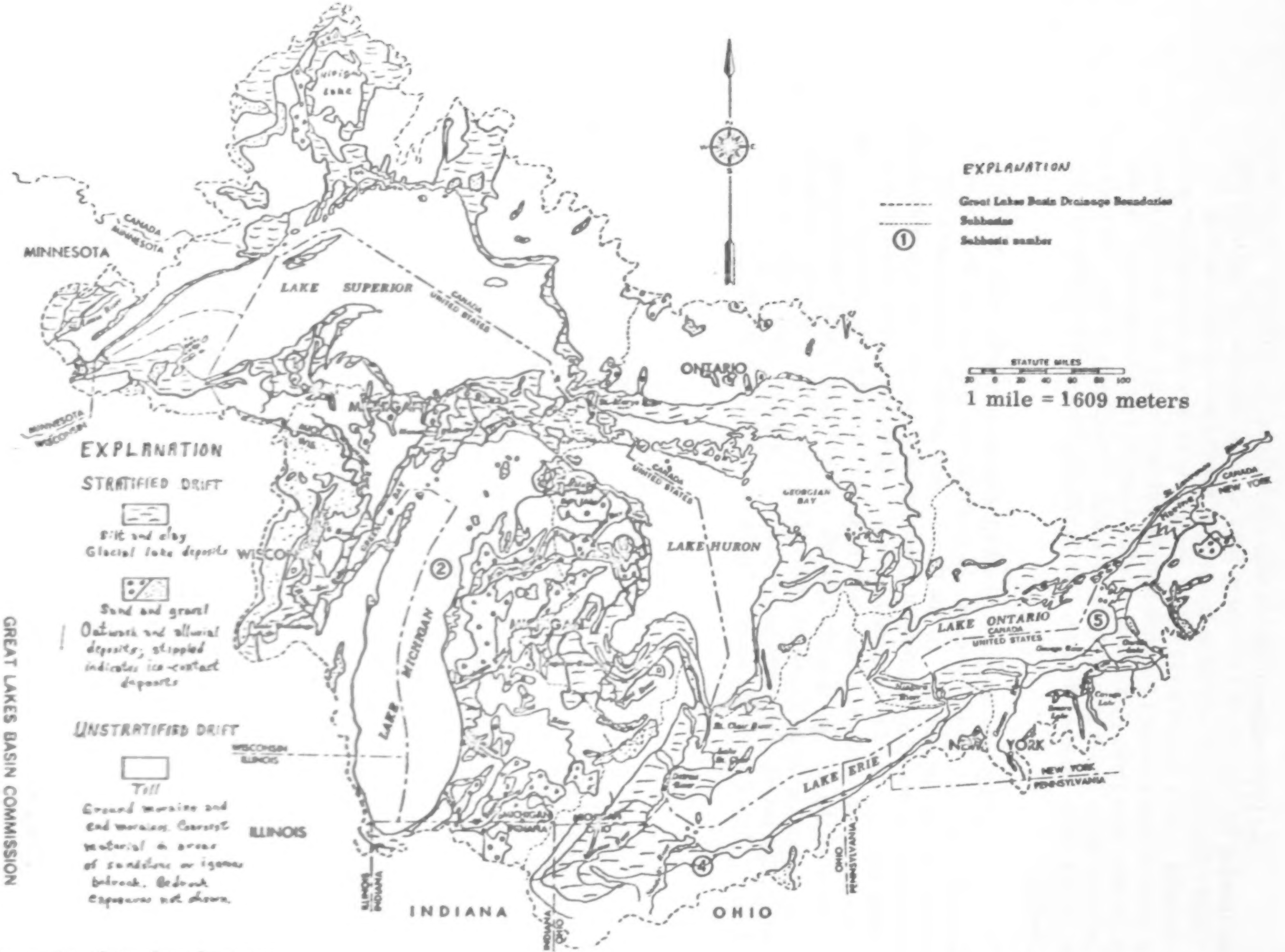
1 mile = 1609 meters

Base by Great Lakes Basin Commission

Adapted from U.S. Geol. Survey, 1965

(from reference 7)

Fig. 7 - Bedrock geology of the Great Lakes basin.



1 mile = 1609 meters

Base by Great Lakes Basin Commission

U.S.A. adapted from Geol. Soc. of America, 1959
Canada adapted from Geol. Survey of Canada, 1968
(from reference 7)

Fig. 8 - Glacial geology of the Great Lakes basin.

The implication of this is that the soils in the valleys of rivers and streams flowing into the Great Lakes may have alluvial deposits of varying thickness. These deposits may extend to the stream mouths and merge with littoral beach deposits. Such deposits are highly permeable to flow of water and/or gas. They possess a high potential for contamination of lake water both directly and through stream base flow. Thus they should be avoided as landfill sites. Moreover, because these areas are likely to have high groundwater tables, the base of landfills could easily become flooded, thus facilitating the contamination of the groundwater.

In addition to the purely geological considerations outlined above, hydrological data can be used to assess the potential for pollution of lake waters by landfills. In its Appendix No. 3, the Great Lakes Basin Commission (1971) presents maps which estimate potential groundwater yield based on determining the base runoff from stream flow-duration curves. The base runoff is taken to be a good indicator of the capacity of the aquifers in the vicinity of the streams to yield water. Because these maps directly indicate regional base runoff, they provide a means for evaluating the pollution potential of landfill sites. Thus areas with high base flows (high potential groundwater yields) may be potentially hazardous for landfill sites. The subject maps are reproduced in figures 9 through 13.

3.5.5.4 Climatological Factors

The potential for contamination of Great Lakes near shore waters is also influenced by climatological factors.

1. Rainfall is significant in that it provides water for percolation into landfills and subsequent surface runoff or infiltration into the groundwater regime. Figure 14 presents average annual precipitation rates.

2. Infiltration rates determine the amount of surface water that percolates into the groundwater regime. Localized percolation through landfills is, of course, determined by the type of cover on the landfill and not by the infiltration properties of the regional soils. However, water infiltrating the ground surrounding the landfill may percolate into the landfill. Thus average infiltration rates as shown in figure 15 are useful indicators of the potential for groundwater pollution by surface water infiltration.

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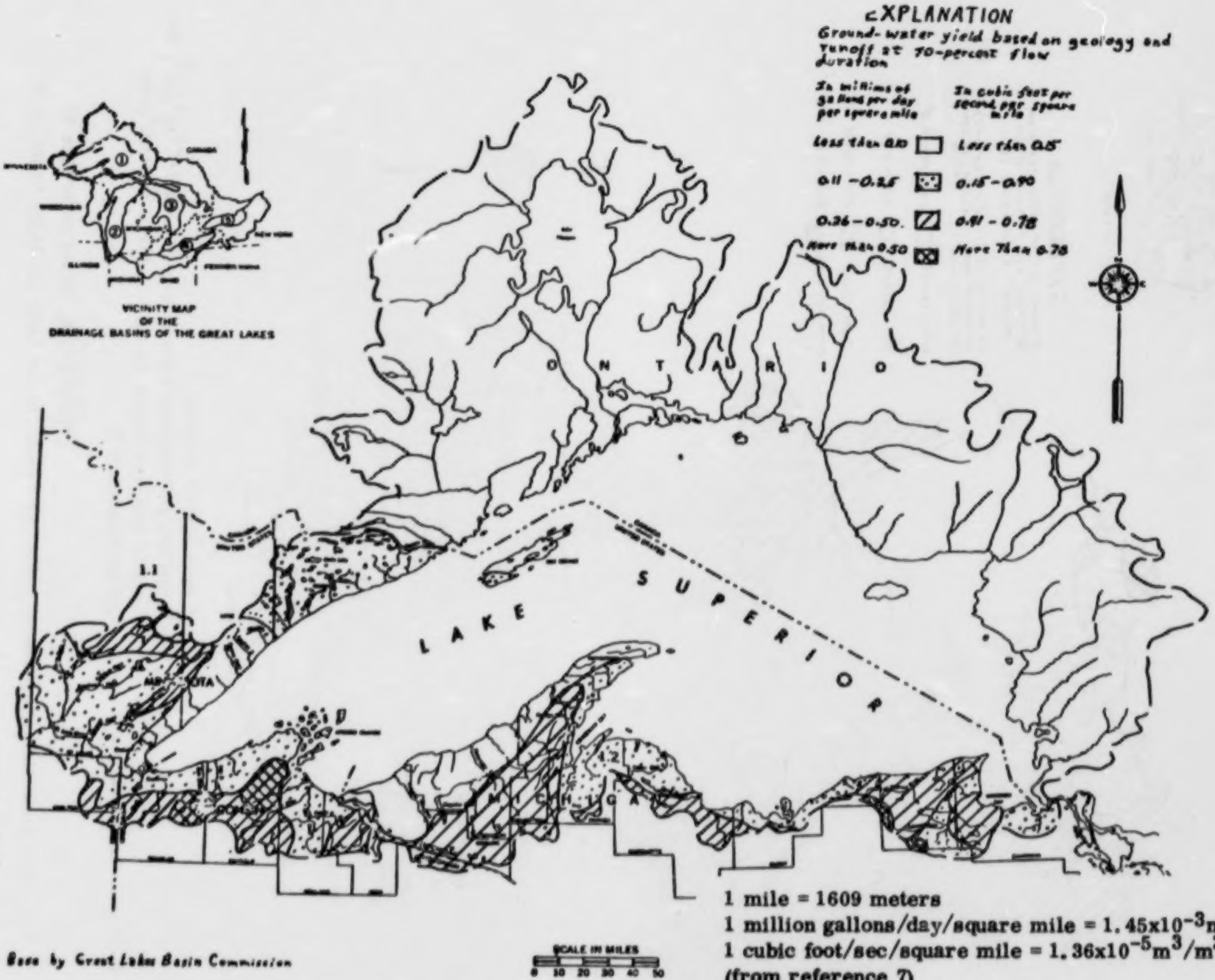
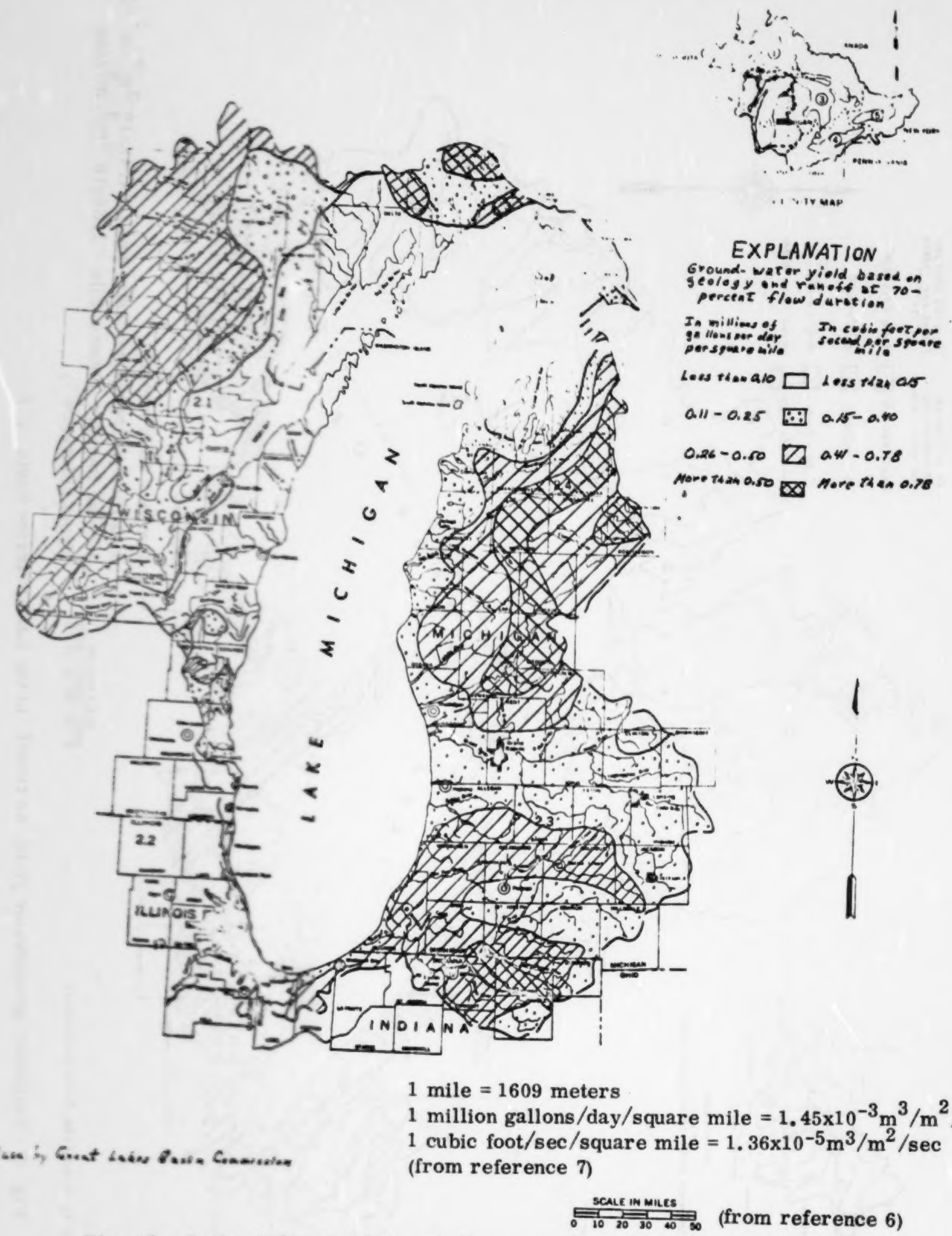

EXPLANATION
Ground-water yield based on geology and runoff at 70-percent flow duration
In millions of gallons per day per square mile
In cubic feet per second per square mile
Less than 0.10 ▭ Less than 0.15
0.11 -0.25 ▦ 0.15-0.90
0.26-0.50. ▨ 0.41 - 0.78
More than 0.50 ▩ More Than 0.78
ONTARIO
LAKE SUPERIOR
MICHIGAN
1.1
1.2
VICINITY MAP OF THE DRAINAGE BASINS OF THE GREAT LAKES
SCALE IN MILES
0 10 20 30 40 50

Base by Great Lakes Basin Commission

1 mile = 1609 meters
1 million gallons/day/square mile = $1.45 \times 10^{-3} m^3/m^2$/day
1 cubic foot/sec/square mile = $1.36 \times 10^{-5} m^3/m^2$/sec
(from reference 7)

Fig. 9 - Estimated groundwater yield, as runoff, in the Lake Superior basin, U.S.


EXPLANATION
Ground-water yield based on geology and runoff at 70-percent flow duration
In millions of gallons per day per square mile
In cubic feet per second per square mile
Less than 0.10 ☐ Less than 0.15
0.11 - 0.25 ⁙ 0.15 - 0.40
0.26 - 0.50 ▨ 0.41 - 0.78
More than 0.50 ⊠ More than 0.78
LAKE MICHIGAN
WISCONSIN
MICHIGAN
ILLINOIS
INDIANA
21
22
23
24

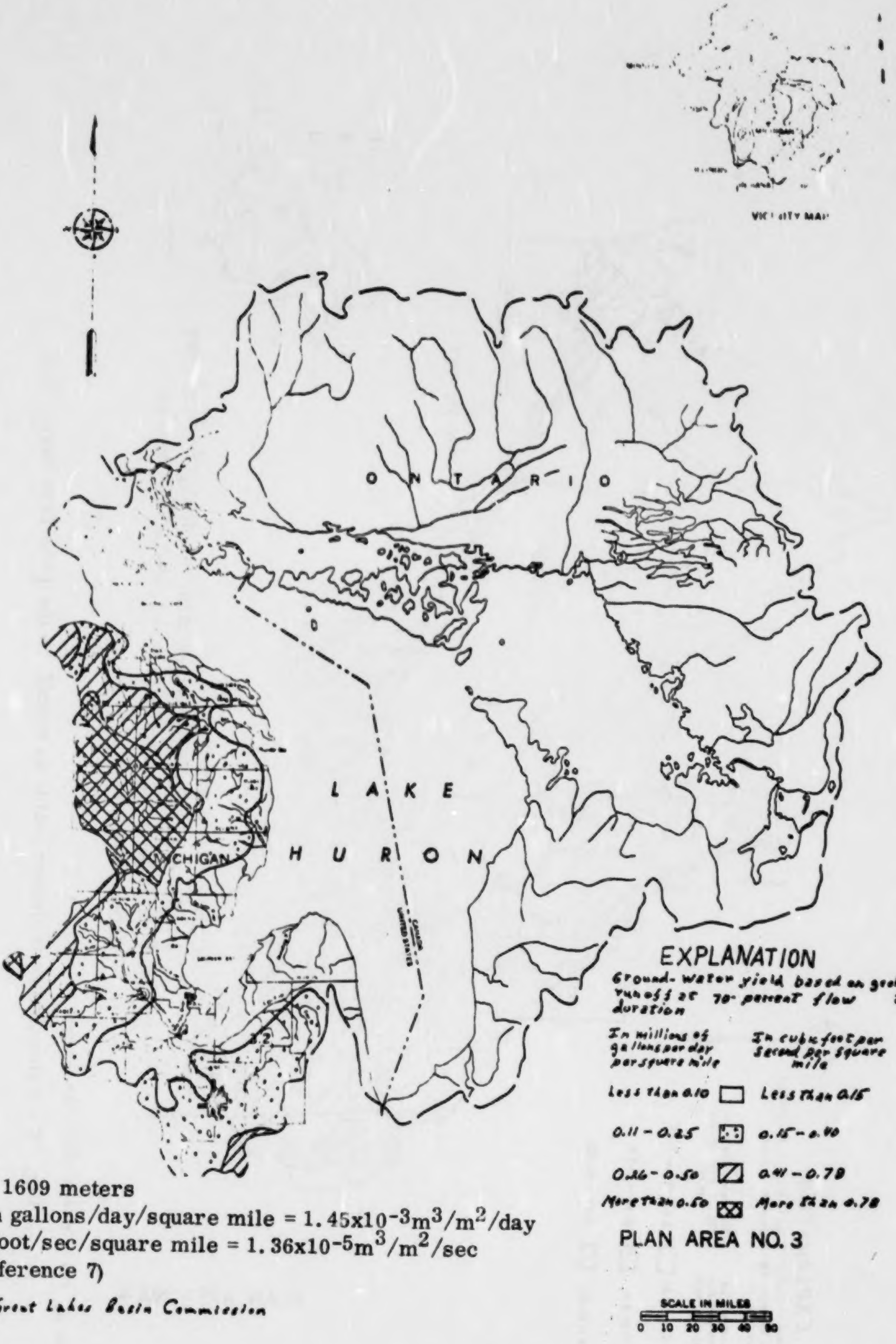
1 mile = 1609 meters
1 million gallons/day/square mile = $1.45 \times 10^{-3} m^3/m^2/day$
1 cubic foot/sec/square mile = $1.36 \times 10^{-5} m^3/m^2/sec$
(from reference 7)

Base by Great Lakes Basin Commission

SCALE IN MILES 0 10 20 30 40 50 (from reference 6)

Fig. 10 - Estimated groundwater yield, as runoff, in the Lake Michigan basin, U.S.

383<


VICINITY MAP
ONTARIO
LAKE HURON
MICHIGAN
CANADA
UNITED STATES
EXPLANATION
Ground-water yield based on geology, runoff at 70-percent flow and duration
In millions of gallons per day per square mile
In cubic feet per second per square mile
Less than 0.10 ☐ Less than 0.15
0.11 - 0.25 ⛶ 0.15 - 0.40
0.26 - 0.50 ▨ 0.41 - 0.78
More than 0.50 ⊠ More than 0.78
PLAN AREA NO. 3
SCALE IN MILES
0
10
20
30
40
50

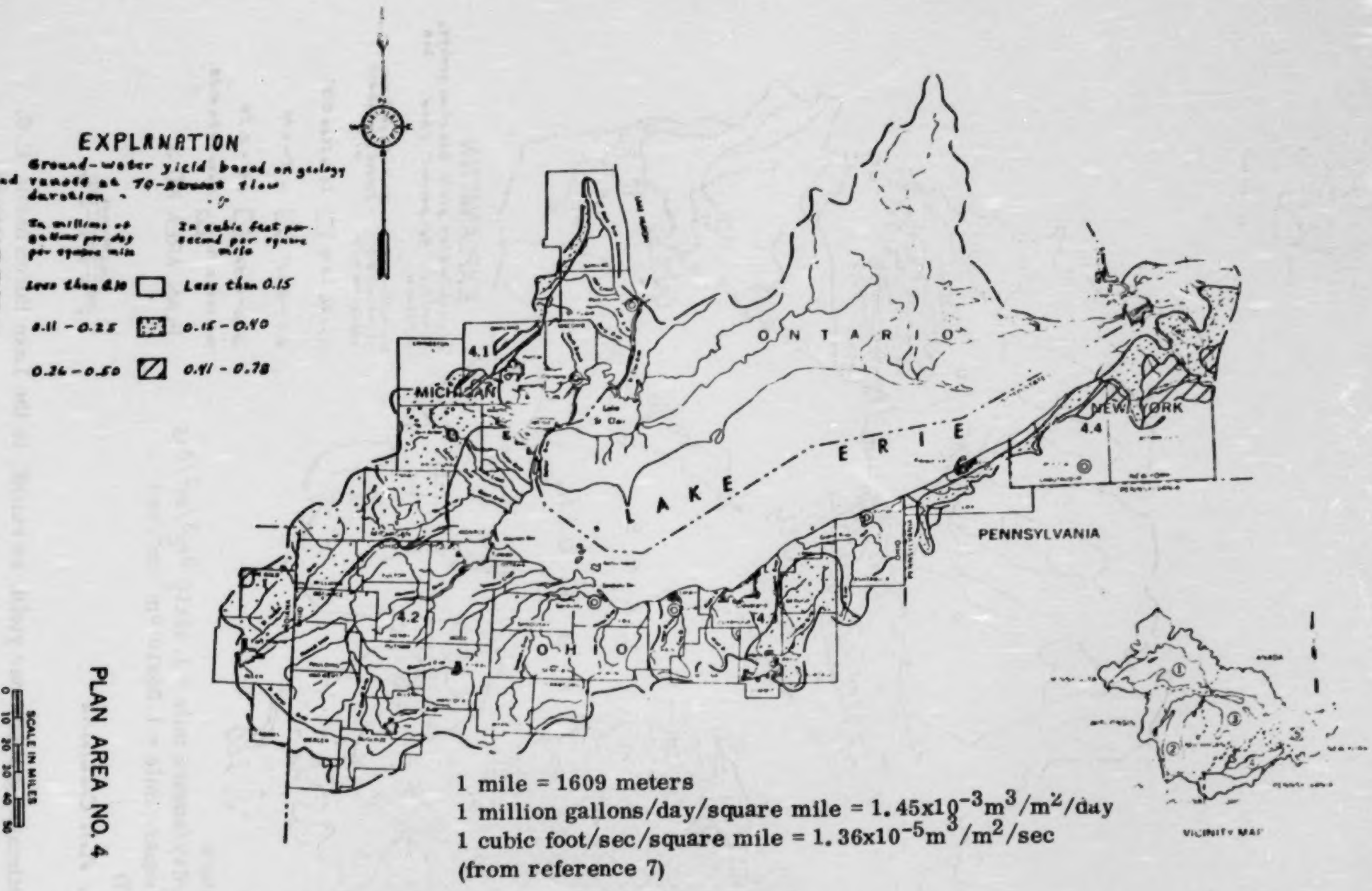
1 mile = 1609 meters
1 million gallons/day/square mile = 1.45x10^{-3}m^3/m^2/day
1 cubic foot/sec/square mile = 1.36x10^{-5}m^3/m^2/sec
(from reference 7)

Base by Great Lakes Basin Commission

Fig. 11 - Estimated groundwater yield, as runoff, in the Lake Huron basin, U.S.

384<

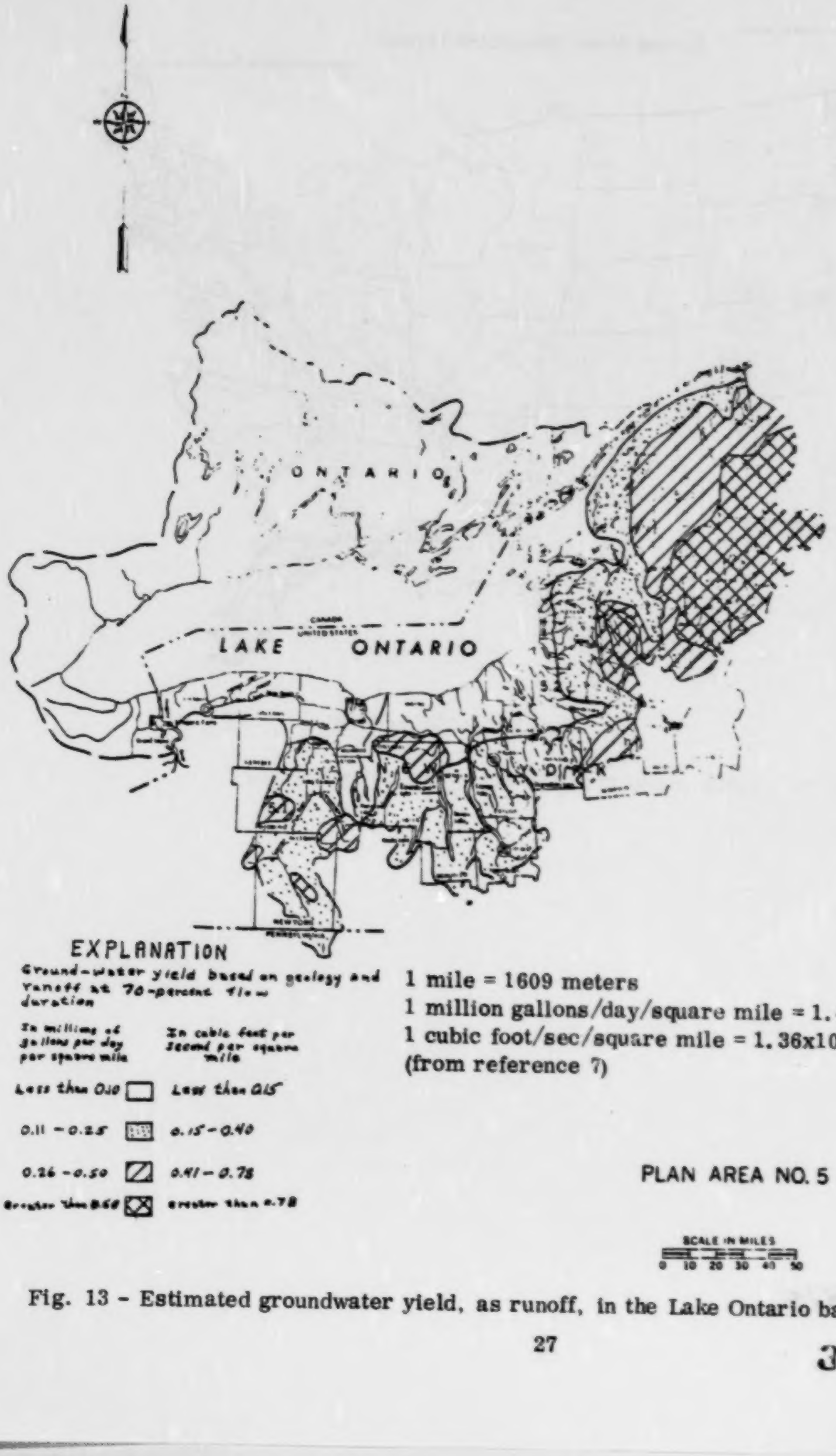
385<


EXPLANATION
Ground-water yield based on geology and runoff at 70-percent flow duration
In millions of gallons per day per square mile
In cubic feet per second per square mile
Less than 0.10 ☐ Less than 0.15
0.11 - 0.25 ▨ 0.16 - 0.40
0.26 - 0.50 ▧ 0.41 - 0.78
ONTARIO
LAKE ERIE
MICHIGAN
NEW YORK
PENNSYLVANIA
OHIO
4.1
4.2
4.3
4.4
VICINITY MAP
PLAN AREA NO. 4
SCALE IN MILES
0 10 20 30 40 50

1 mile = 1609 meters
1 million gallons/day/square mile = 1.45x10^{-3}m^3/m^2/day
1 cubic foot/sec/square mile = 1.36x10^{-5}m^3/m^2/sec
(from reference 7)

Base by Great Lakes Basin Commission

Fig. 12 - Estimated groundwater yield, as runoff, in the Lake Erie basin, U.S.


ONTARIO
CANADA
UNITED STATES
LAKE ONTARIO
NEW YORK
PENNSYLVANIA
EXPLANATION
Ground-water yield based on geology and runoff at 70-percent flow duration
In millions of gallons per day per square mile
In cubic feet per second per square mile
Less than 0.10 ☐ Less than 0.15
0.11 - 0.25 ▒ 0.15 - 0.40
0.26 - 0.50 ▨ 0.41 - 0.78
Greater than 0.50 ⊠ Greater than 0.78
PLAN AREA NO. 5
SCALE IN MILES
0 10 20 30 40 50

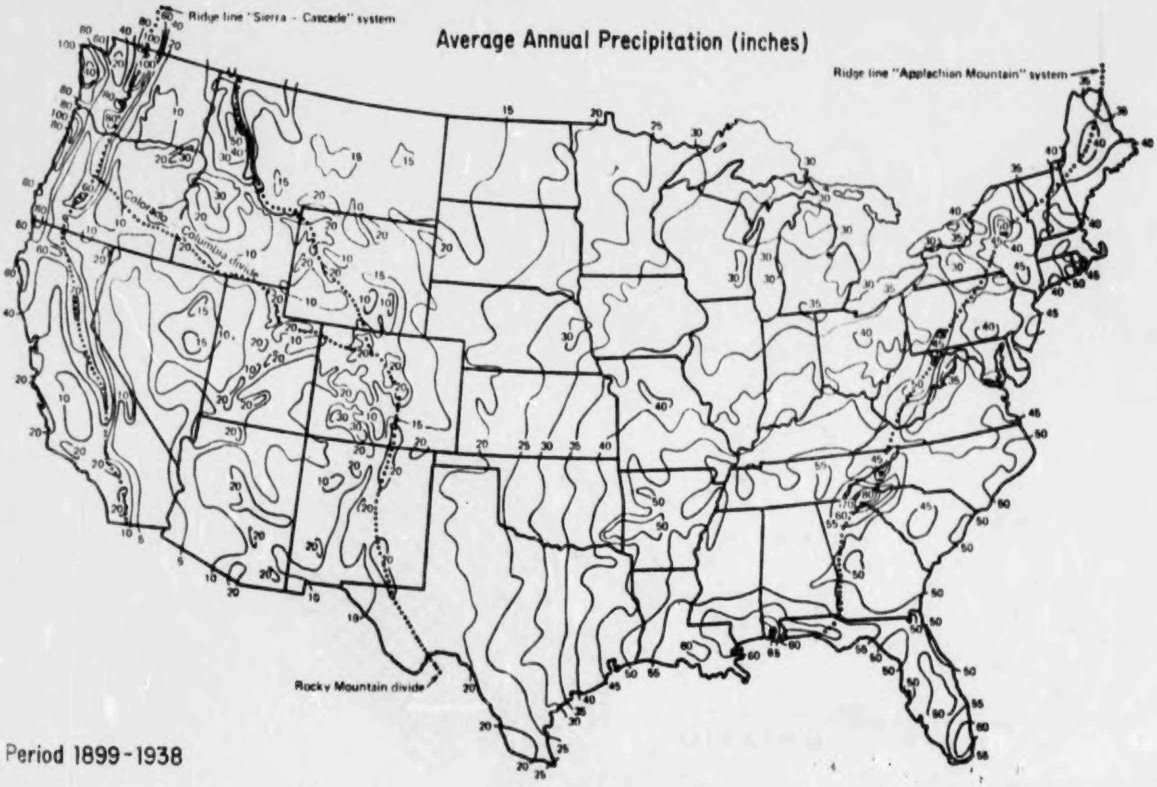
1 mile = 1609 meters

1 million gallons/day/square mile = $1.45 \times 10^{-3} m^3/m^2/day$

1 cubic foot/sec/square mile = $1.36 \times 10^{-5} m^3/m^2/sec$

(from reference 7)

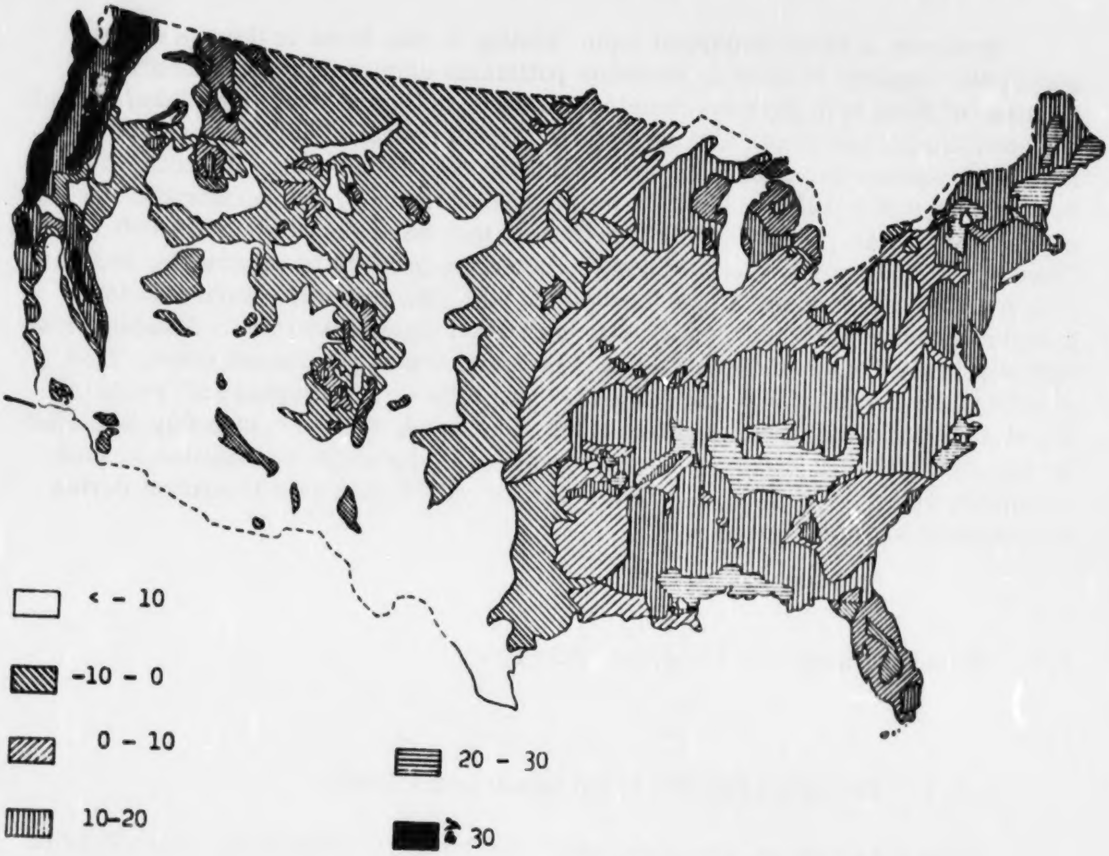
Fig. 13 - Estimated groundwater yield, as runoff, in the Lake Ontario basin, U.S.


Ridge line "Sierra - Cascade" system
Average Annual Precipitation (inches)
Ridge line "Applachian Mountain" system
Columbia divide
Colorado
Rocky Mountain divide
Period 1899-1938

1 inch = .0254 meters

Fig. 14 - Mean annual precipitation. (from reference 15)

387<



1 inch = .0254 meters

Fig. 15 - Average potential infiltration, inches. (from reference 5)

3.6 Natural Renovation Mechanisms

Current problems of contamination by landfills are probably only locally significant in the Great Lakes basin. Thus the concept of renovation as it applies to remedying existing problems is not applicable.

However, a more important topic relating to this issue is the use of the absorptive capacity of soils to attenuate pollutants emmanating from landfills. Because of their high physico-chemical activity, soils and their associated biological constituents can detain and decompose large amounts of pollutants. The detention capacity is represented by a partition coefficient giving the ratio of the concentration of a pollutant in soils to the concentration of that pollutant in the pore water or gas. This partition coefficient may be of the order of 10,000:1. However, it is important to note that the detention process is reversible, and as less polluted water or gas flows through the soil, the soil will return pollutants back to the system. Thus, while soils perform a significant role in detaining non-degradable pollutants like metals, they do not serve as permanent sinks. It is essential, then, that these pollutants from landfills be intercepted and treated at the site. Many organic pollutants, on the other hand, will be completely degraded by microbial films in the soil. Organic acids are especially susceptible to such decompensation. The soil, therefore, may be relied upon as a treatment device for degradable organic pollutants.

3.7 Probable Changes in Land Use Activities

3.7.1 Existing Landfills in the Great Lakes Basin

Current data on the locations, sizes and tributary populations of landfills in the Great Lakes basin were requested of relevant state and federal agencies. The data obtained are presented in supporting data filed in USEPA Chicago office.

There are several deficiencies in these data. First, the state and federal agencies do not maintain records of sufficient detail to evaluate the impact of these fills on water quality. Mr. John Connally, Technical Information Officer of the Solid Waste Information Retrieval System (SWIRS), indicated the data in SWIRS were obsolete and fragmentary and recommended that data be sought from state agencies. Of the eight states within the Great Lakes Basin only Illinois and Wisconsin appear to have computerized information retrieval systems. It is, of course, very costly to obtain large amounts of data from normal paper files. Probably for this reason, Michigan was unable to supply the data requested. Minnesota did not even respond to the letter requesting it, although, a representative of the Solid Waste Division of the Minnesota Pollution Control Agency had previously indicated by telephone that the information would be forthcoming.

Furthermore, only Indiana keeps records of the actual physical location of landfills. The other states keep the mailing addresses of the owners. Finally only Pennsylvania and Wisconsin were able to supply data on the tributary population to the landfill sites. No state supplied data on the amounts of solid waste placed into the fills nor the rate of solid waste placement, but these data were not requested.

It seems clear that detailed data on landfill location and operation can only be obtained from the operators themselves. State and federal records frequently consist of a listing of these operators and so only serve as a starting point. Unfortunately, evaluation of the impact of landfills on water quality requires knowledge of the proximity of the fills to surface and groundwaters, the nature of the fill material, the amount of fill material and the operational procedures. Current state and federal records are inadequate to perform this evaluation.

3.7.2 Projected Future Activities

3.7.2.1 Domestic and Industrial Refuse

The per capita waste is not likely to change significantly in the future. Thus estimation of landfill use map, as a first approximation, be projected on the basis of anticipated population growth.

3.7.2.2 Dredge Disposal

If landfills are to be used for disposal of polluted dredge spoil, the projected future use may increase significantly. Dredging generates some 10 million cubic yards (7.6 million cubic meters) of spoil annually. While landfills are not the only means currently being considered for such disposal, they may be relied upon increasingly in the future.

3.8 Projected Seriousness of Future Pollution Problems

The seriousness of future pollution problems depends largely on the control technology adopted. The annual projected leachate production for the U.S. is in excess of 50 billion gallons per year. The proper treatment of this quantity of polluted material poses a technological problem which will require a significant financial outlay.

3.9 Review of Institutional Arrangements to Regulate Land Use

Federal and state legislation and regulations that relate directly to pollution from the disposal of solid waste are of fairly recent origin. Prior to the passage of Public Law 89-270, The Solid Waste Disposal Act of 1965, there was no federal legislation related to solid waste disposal. The purpose of this act is to initiate and accelerate a national research and development program for new and improved methods of proper and economic solid waste disposal, and to provide technical and financial assistance to State and Local governments to plan, develop and conduct solid waste disposal programs. However, there are no federal guidelines included in this Act for the design, construction and operation of solid waste disposal systems.

The Federal Water Pollution Control Act Amendments of 1972, Public Law 92-500, does encourage and support control of water pollution from all activities, but does not provide specific guidelines for the design and operation of solid waste disposal systems.

In the absence of specific Federal guidelines, most States consider solid waste disposal as a problem to be handled at the State or local level, and have adopted their own regulations to control water pollution from these facilities. The regulations for the State within the Great Lakes Basin are reviewed briefly in the following paragraphs:

Illinois - The solid waste program in Illinois is administered by the Illinois Environmental Protection Agency under the provisions of the Illinois Environmental Protection Act of 1970. They have established Solid Waste Regulations which include provisions for the issuance of a permit to operate a waste disposal site and regulating siting and monitoring criteria for these operations.

Minnesota - The solid waste program in Minnesota is administered by the Solid Waste Division of the Minnesota Pollution Control Agency, which was established under provisions of Chapter 116 of the Minnesota Statutes of 1971. The whole program is geared to the local level, but the Division must review and approve plans submitted by the counties. The Division has established Solid Waste Regulations which include provisions for the issuance of a permit before a waste disposal site can be operated. These regulations also include provisions for the establishment of a monitoring system to limit ground and surface water pollution from the site.

Wisconsin - The Solid Waste Management Section of the Wisconsin Department of Natural Resources administers the solid waste program in Wisconsin. Chapter 83 of the Wisconsin Laws of 1967, which was directed at environmental protection, authorized the Department of

Natural Resources to adopt minimum standards for all solid waste activities in the State, and permitted them to establish an annual licensing program to ensure compliance with these standards.

Chapter 130 of the Wisconsin Laws of 1971 authorized counties to plan, construct and operate solid waste facilities. It also directed the Department of Local Affairs and Development to adopt minimum criteria for the plans submitted by the counties, and authorized the Department of Natural Resources to review and approve these plans.

More recently, the state legislature has approved the Solid Waste Recycling Act creating an operating Agency to plan and construct facilities to recycle waste materials.

Michigan - The Michigan Department of Natural Resources administers an annual licensing program under the provisions of Public Act 87, (1965) as amended, for all sanitary landfills operations, transfer stations, processing plants and hauling vehicles in the state. The Department attempts to control the pollution of surface and ground water from existing operations by requiring improvements before the license is re-issued.

Sites that are proposed for new solid waste disposal facilities are now reviewed by both the local health agencies, and the Department of Natural Resources; and geological and engineering information are required before the site is approved.

Ohio - The Technology Development and Resource Recovery Section of the Ohio Environmental Protection Agency administers the solid waste program in Ohio under the general provisions of Section 37-34 of the Ohio Revised Code of 1967, as amended. Under regulations just adopted, the Agency must approve the plans for new solid waste disposal facilities before they will issue a "permit to install". Also included in these regulations are provisions to conduct a public hearing, if requested, for all proposed facilities.

Annual licensing of existing disposal sites is administered by local health departments which have been certified by the OEPA to conduct these reviews.

Indiana - The solid waste program in Indiana is administered by the Solid Waste Management Section of the Indiana Board of Health. Under provisions of the Refuse Disposal Act (IC 1971; 19-2-1) and the Environmental Management Act (IC 1971; 13-7), the Board of Health is authorized to approve all solid waste disposal processes prior to the aquisition of the facility, and is permitted to establish regulations to carry out the provision of the Acts. They are currently developing regulations to administer a bi-annual permit system to control the operation of solid waste disposal systems. The county health officers also enforce their own regulations for the control of these systems.

Pennsylvania - The Division of Solid Waste Management, Bureau of Land Protection, Department of Environmental Resources administers the solid waste management program under the provisions of the Pennsylvania Solid Waste Management Act of 1970 (P. L. 788). Under the planning phases of this Act, every community that has a population density greater than 300 persons per square mile must submit a plan for the disposal of its solid waste. This feature of the Act has caused all communities to become aware of the problems associated with solid waste disposal. Under the enforcement phase of the Act, every proposed facility must submit designs and engineering plans before a permit to operate the facility can be issued. If conditions warrant it, provisions must be made to include liners or seals to prevent groundwater contamination and to provide treatment facilities to eliminate water pollution. Special permits must also be obtained before hazardous and toxic wastes can be disposed of at individual sites.

New York - The Solid Waste Management Division in the Department of Environmental Conservation administers the solid waste program in New York under the provisions of the Solid Waste Management Act of 1972. Under the terms of this Act, the Division may establish rules and regulations for all aspects of solid waste disposal beyond the collection stage. They have developed a permit system which requires that engineering plans based on established criteria be submitted and approved before a permit to operate can be issued. The Division also provides for the certification of operators of landfill sites.

Other programs include the registration of collectors and haulers, and a grants program for the recycling and disposal of solid waste.

In general, the States within the Great Lakes Basin feel that adequate legislation directed at the control of pollution from solid waste disposal facilities is available. They report that a few significant problem areas do exist, but all feel that these problems can and will be corrected under their current permit and licensing systems. There are very few problems at newer landfill sites, as more rigorous inspection and approval systems have done much to eliminate the water pollution potential.

Some new legislation is to be expected in connection with the disposal of hazardous and toxic materials, and more effort will be expended on developing systems to recycle solid waste in the future.

Section 4

SUMMARY OF RELEVANT ONGOING OR PROPOSED RESEARCH, DEMONSTRATION OR MONITORING PROGRAMS

4.1 Past Research

The most recent formal summary of research and demonstration programs is found in:

(1) Solid Waste Management Demonstration Grant Projects - 1971, USEPA

(2) Summaries of Solid Waste Research and Training Grants - 1970.

4.2 Ongoing Research and Demonstration Programs

4.2.1 Pollution by Leachates

Information on current programs, particularly as they relate to the Great Lakes Basin, has been obtained from Mr. Dirk R. Brunner, Senior Research Sanitary Engineer, Solid and Hazardous Waste Research Laboratory, USEPA. The following is quoted from Mr. Brunner's letter of January 2, 1974 in response to our request:

"Landfill-oriented research since 1971 is not summarized in the publications being sent. Therefore, the following is provided as a brief update. More specific information is available on request.

"The start of a federal research program evaluating the sanitary landfill method is not clear but might start with the Merz and Stone work of the 60's. This research grant was a potpourri of studies evaluating sanitary landfills in the southern climate of California. Particular emphasis was placed on landfill gas concentration and production, initial evaluation of an aerobic sanitary landfill, and limited leachate and other landfill related work. The study represents the only presently published data on landfill gas productions.

"The sanitary landfill method was more recently studied under humid, temperate conditions by Fungaroli, et. al., at Drexel University. I have enclosed some reports of their continuing work. The significance of this project is that leachate is shown to be a highly contaminated, though small volume wastewater, even if the best principles of sanitary landfilling are practiced. The volume of leachate is, of course, dependent on the net infiltration through cover soil when the waste is deposited above groundwater. This work is continuing but will terminate in June 1974.

"The northeastern Illinois study by Hughes, et. al., also verified leachate production and strength, demonstrated a tendency for groundwater mounds to form under sanitary landfills, and showed that soil can act as an effective cleansing agent for permeating leachate or leachate contaminated groundwater. This observation was also made by Anderson, Dornbush, Langmuir, and Parizek at Pennsylvania State University. Insufficient quantitative data exists, however, to predict the performance of specific soils.

"There was a lack of data concerning leachate treatment and attenuative capacity of soils. To alleviate this, a research grant to Robert Ham at the University of Wisconsin, and a research contract with Ed Chian at the University of Illinois were awarded to investigate leachate treatment. The study of attenuative capacity of soils was split and awarded to the University of Arizona and the Illinois Geological Survey. Results to date indicate that biological treatment of leachate is most practicable. Both aerobic and anaerobic processes perform satisfactorily. Leachate can be treated in a domestic wastewater activiated sludge plant so long as leachate represents less than 5 percent of the total flow. Phosphorus tends to become limiting at higher percentages of leachate. Physical and chemical treatment methods have been found to be inadequate for treating raw, fresh leachate, but will probably be very useful for polishing of biologic effluents and treating old leachates where necessary.

"No significant accomplishments have been made with the attenuation in soils work. Experimental facilities are just now operational; significant data is anticipated in the next few months.

"A slightly different twist in traditional sanitary landfill design was provided by Fred Pohland of Georgia Tech. He is currently studying the concept of recycling leachate through the sanitary landfill to accelerate and control the ongoing anaerobic decompensation processes in the fill. Results look very promising, as the organic fraction of leachate is reduced to very low levels in less than 1 year. The question of how to handle the large volumes of leachate during a long-term recycling procedure has not been resolved."

4.2.2 Pollution by Gas

Drs. Moore, Wu, Sandhu and Sykes of The Ohio State University are currently developing models and applications charts for predicting movements of gases around sanitary landfills. The work is under EPA sponsorship.

Section 5

NATURE AND AVAILABILITY OF TECHNOLOGY TO COPE WITH POLLUTION PROBLEMS

5.1 Nature of Technology

The technology required to control pollutant transport from landfills draws strongly on technology previously developed for other applications. The steps required are:

(1) interception of pollutant

(2) collection of pollutant

(3) handling (recycling and/or decontamination) of pollutant

In order to render landfill operation safe, various types of barriers have been proposed. Among the reasons for imposing barriers have been to:

(1) exclude rodents, flies and other pests

(2) reduce wind blowm refuse

(3) reduce fire hazards

(4) exclude rain water from percolating into the top of the landfill

(5) eliminate groundwater seepage into the sides of the landfill

(6) avoid infiltration of landfill leachate into the ground around and beneath the landfill

(7) reduce movement of landfill gases into the ground and/or surrounding the landfill.

On the other hand, vents or drains have also been proposed for such reasons as to:

(1) allow landfill gases to escape to the atmosphere

(2) collect landfill gases for disposal by burning (methane)

(3) collect leachate for proper disposal

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(4) provide air to the landfill if aerobic decomposition is desired

(5) expell gas and water to allow settlement and consequent densification of the landfill so that construction may take place on the landfill surface

(6) draw down the groundwater level and cause a net flow of groundwater toward the landfill on all sides irrespective of the regional groundwater flow pattern.

Barriers, vents and/or drains are seldom mutually compatible, and the landfill designer is frequently faced with conflicting design considerations which must be reconciled.

Technology for handling contaminants consists of one or more of the following:

(1) recycling contaminants through the landfill to accelerate decomposition

(2) reclamation of such by-products as methane for secondary use

(3) treatment of contaminants in special purpose or existing treatment plants to effect decontamination.

5.2 Practice of Technology

Present and impending legislation will have the effect of forcing the use of appropriate technology in designing and operating landfills. Many examples of proper operation of landfills exist and essentially all proposed operations must comply with appropriate standards.

5.3 Range and Effectiveness of Management Technology

It is in this area that the major problems arise. While an adequate technology exists, its implementation imposes major political and economic problems. Previously little or no control was used in many landfill operations. As a result, landfill operators have almost no experience upon which to draw. Moreover, minimal budgeting is available to institute control measures. Modern technology requires a significant initial financial investment both in the planning stages (where the return on investment may be zero) and in instituting seals, collection systems and effluent treatment facilities. Political pressures against such investments can be significant.

5.4 Importance in Reducing Pollution

Proper control of pollution at the landfill site is essential if control is to exist at all. Landfills are in the class of point source pollutors, and the most economical and effective control is that which is initiated at the source.

5.5 Recommended Priorities for Adopting Technology

There is very little opportunity for staging the adoption of technology for pollution control. Thus it is recommended that future installations incorporate complete control technology.

5.6 Need for New Technology

The basic technology for control of pollution around landfills currently exists. However, future research in the area of economy and efficiency of operation will be extremely important. This is likely to be best accomplished through demonstration projects on full scale landfills.

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Section 6

NEED FOR NEW RESEARCH, DEMONSTRATION AND MONITORING PROGRAMS

Because technology has not been previously extensively applied to landfills, problems may be encountered in new controlled facilities. Thus the major current requirement is for careful monitoring of the performance of controlled landfills. Moreover experimentation in the effectiveness of various, modifications in operating procedure for a given landfill would be helpful in increasing efficiency of operation.

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Section 7

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Land Use/Water Quality Relationships in the U. S. Great Lakes Basin
Task A: To assess problems, management of programs and research...
Category A15 - Land Fills (dredging activities)

DREDGING ACTIVITIES

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To be used as portion of the U. S. Task A Report on GREAT LAKES POLLUTION FROM LAND USE ACTIVITIES by the International Joint Commission - prepared in partial fulfillment of U. S. Environmental Protection Agency Contract No. 68-01-1598

August 1974

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Section 1

SUMMARY

1.1 Introduction

Some 10 million cubic yards (7.6 million cubic meters) of sediment are dredged from the Great Lakes basin waters each year. This material is disposed of by open lake, offshore and alongshore, and on land methods. All of these present a hazard for repollution of the lake waters. The pollutants released include nutrients, heavy metals, oil and grease, and pesticides. While dredging is practiced in all of the lakes, the quantities are larger in Lakes Michigan and Erie and in the St. Clair - Detroit River system.

Current legislation requires the diked disposal (near shore or on land) of all polluted wastes. Therefore the threat of contamination of near shore waters is potentially increasing.

1.2 Summary of Findings and Conclusions

(1) Hopper dredges four of which perform 75% of 10 million cubic yards, (7.6 million cubic meters) annual dredging in the Great Lakes, are the most polluting type of dredging equipment currently in use.

(2) Open water dumping, practiced with unpolluted dredge spoil in the Great Lakes, results in relatively great dispersion of sediment in lake water.

(3) Offshore and alongshore diked disposal and landfill disposal methods are potentially the least polluting provided proper precautions are taken to seal the areas and treat the effluent properly.

(4) All of the Great Lakes except Lake Ontario have been found to contain polluted sediments. Polluted harbors have been so designated by the EPA.

(5) Pollution transport mechanisms are diverse and have only begun to be studied.

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(6) **Institutional control over dredging and dredge disposal is solely by the EPA in the Great Lakes basin.**

(7) **An active and well planned research program is currently being executed by the U.S. Corps of Engineers Waterways Experiment Station. However, there seems to be little attention given to relevance to local or regional problems.**

(8) **Technology to control pollution during dredging and open water disposal is poor at best.**

(9) **Technology to control pollution from diked disposal areas and landfills is presently being developed.**

Section 2

SUPPORTING MATERIAL

2.1 Introduction

While the objectives of this study are to discuss the pollution potential for nearshore waters, the scope was expanded to include open water dumping. This was done under the premise that lake currents result in near shore contamination from open water dumping.

This summary paper specifically excludes measures designed to avoid sediment being transported into the lakes initially. This alternative may be a viable solution to the problem and deserves full consideration.

2.2 Scope of Study

Access to the literature in this area is not particularly easy. However two major federal agencies, the Army Corps of Engineers and the EPA, control the execution and regulation of dredging activities respectively. The Corps of Engineers has done a thorough job of documenting dredging activities in published documents. The EPA is most helpful in providing information, however this information is not available in a coordinated form. Thus recourse to scattered individuals is necessary in order to obtain desired information. Nevertheless, both agencies were most cooperative in providing information for the present study.

2.3 Study Procedure

Much of the material used in this state-of-the-art report was found in the existing literature. In many cases factual information has been taken from these sources with direct acknowledgment. In other cases, direct acknowledgment would result in an unnecessarily cumbersome format. Moreover, paraphrasing a well written text serves only to weaken it. Thus the writers call particular attention to the publications listed under References and acknowledge the great extent to which they were used.

In addition to published information, contact was made with numerous individuals in the Corps of Engineers and in the EPA.

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Section 3

REVIEW OF FINDINGS OF PREVIOUS STUDIES

3.1 General Description of Land Use Activities

3.1.1 Introduction

Dredging is defined as the process of removing materials from underwater and their subsequent disposal. The process includes two operations: (1) excavation of the materials and (2) conveyance to and release of the materials at the disposal site. Equipment for dredging operations on the Great Lakes are of two types: (1) mechanical and (2) hydraulic. Dipper and clamshell dredges are mechanically operated, while hopper and pipeline dredges are hydraulically operated. Mechanical dredging requires auxiliary equipment, consisting of scows and tugs, to receive the dredged materials and transport them to the disposal site. Hydraulic dredges combine the digging and disposal operations in one piece of equipment (U. S. Army Corps of Engineers, 1969).

3.1.2 Equipment

3.1.2.1 Dipper Dredges

Dipper dredges are used for heavy duty excavations. Their main feature is a power operated dipper stick with a bucket at its end which can be moved forward, vertically and horizontally from boom. This type of dredge is especially useful for "new work" dredging and breaking up hard compacted material, including some types of ledge rock. The dredge is held in position by forward and stern spuds. During operation, the boom is swung around to empty the bucket into a scow. Rates of dredging depend on the size of the dipper bucket, nature of the material, and depth of the cut. Rates in the Great Lakes have been reported as high as 400 cubic yards/hour (306 cubic meters/hour) (U. S. Army Corps of Engineers, 1969).

Dredging operations can be classed in two general categories: (1) maintenance and (2) new work dredging. Maintenance dredging comprises the removal of soft and easily excavated sediments deposited since the last dredging. It is generally required annually in the commercially more important harbors and less frequently in harbors for light-draft recreational craft. New work dredging is employed to improve a harbor area or channel by widening or deepening. This type

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of dredging removes materials, ranging from limestone to compacted clays, which were deposited in older geologic times. In performing new work dredging some small amounts of very recently deposited material is also removed. New work dredging is performed by the Corps of Engineers only when authorized and funded by Congress.

3.1.2.2 Clamshell Dredges

Dredges of this type consist of a clamshell bucket suspended by cables from a forward extending boom which can swing about the bow of the dredge. Clamshell dredges are most commonly used to excavate soft or cohesive underwater materials. They are especially useful for deep digging and for dredging in close quarters alongside structures. Maintenance dredging in winding river channels is usually done with clamshell dredges. Spuds or anchors are used to position and maneuver these dredges. Like dipper dredges, the dredged material is usually loaded onto a scow. Large clamshell dredges with 12 cubic yards (9.2 cubic meters) buckets excavate up to 400 cubic yards/hour (306 cubic meters/hour) when excavating soft, light-weight material. Approximately 20 percent of all dredging done in the Great Lakes is accomplished by clamshell dredges (U.S. Army Corps of Engineers, 1969).

3.1.2.3 Pipeline Dredges

Pipeline dredges excavate bottom materials with a revolving cutter surrounding the intake end of a suction pipe. The cutter and suction pipe are mounted on a ladder frame hinged at the forward end of the dredge for vertical movement. A pumping unit sucks up material at the intake end of the suction pipe and discharges the material through a trailing pipeline to the disposal site. These dredges are generally equipped with two stern spuds and forward anchors to swing the hull around one of the stern spuds. By alternately raising each of the spuds, the dredge excavates transversely across the area to be cut and "walks" for dredging sandy, clayey, or silty bottoms which have sufficient depths of cut for economical operation. Generally, these dredges are designated by the diameter of the discharge pipe; sizes range from small 6-inch (.16 meter) portable dredges to mammoth 36-inch (.91 meter) dredges over 100 feet (30.5 meters) in length. Pipeline dredges usually contain their own power unit, but some are electrically driven with shore current. Rates of output depend on many factors: (1) horsepower of the pumping and cutter head machinery, (2) length of pipeline, (3) elevation of disposal site, (4) use of booster stations and (5) nature of the material.

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3.1.2.4 Hopper Dredges

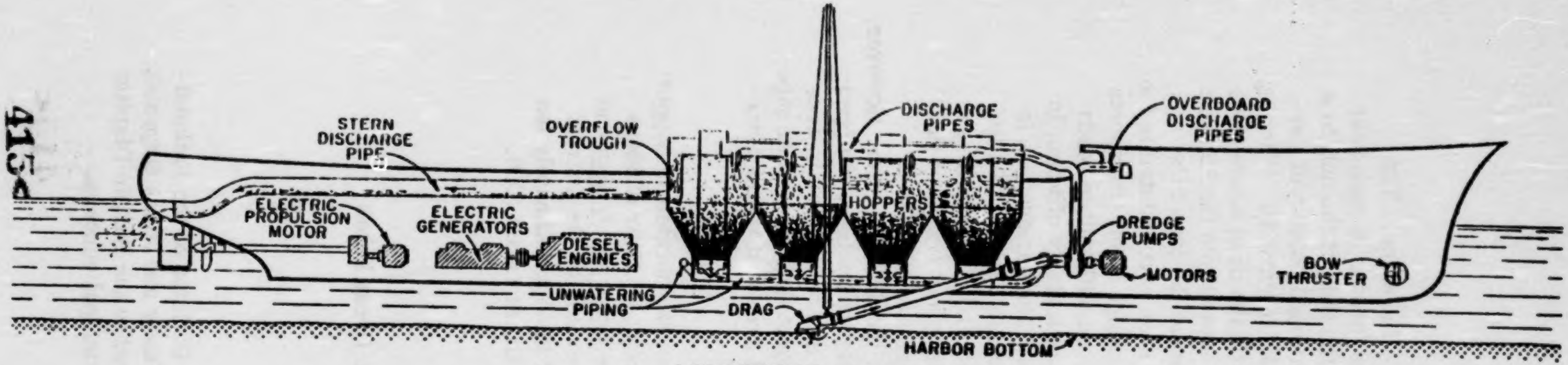
Hopper dredges are essentially self-propelled ships. The dredging apparatus consists of one or more dredging pumps located in each hold which are provided with a suction pipe leading out through the side of the hull to a flexible connection that permits raising and lowering the external portion of the suction pipe, which is equipped with a drag head at its intake (Figure 1). Pumping goes on while the dredge is underway at slow speed and while the drag heads slide over the sediments to be dredged. The dredgings are discharged into the hoppers where they settle. Fine material and excess water overflow at the top of the hoppers. Dredging continues until an economical load has been accumulated in the hoppers. At this time, the pumps are shut down, and the dredge itself transports its load to the disposal site. Hopper dredges are not equipped with cutter heads and work well only in uncompacted sediments. They are particularly efficient in removing a thin layer of sediment covering extensive areas. Hopper dredges in use on the Great Lakes range in capacity from 920 to 2,700 cubic yards (703 to 2063 cubic meters) (Table 1). The rate of performance depends upon the length of time required to fill the hoppers, and on the speed and length of travel of the vessel to and from the disposal site. Normally, the hoppers are emptied by opening doors at their bottom while the dredge passes over the disposal site. However, in recent years most of the hopper dredges in the Great Lakes have been equipped with piping through which they can pump out the hoppers to an on-shore or in-lake disposal site. These dredges tie up to a mooring, and connect their discharge pipe to a pipeline through which the dredgings flow to a disposal area that would otherwise be inaccessible to the dredges.

Presently the U.S. Army Corps of Engineers operates 16 hopper dredges in the coastal and inland waterways of the United States. Four of these maintain authorized project depths on the Great Lakes: the *Hoffman*, *Lyman* and *Markham* operated by the Buffalo District and the *Hains* operated by the Detroit District. Hopper dredges presently do about 75 percent of the approximately ten million cubic yards of annual maintenance dredging on the Great Lakes (U.S. Army Corps of Engineers, 1969).

3.1.3 Corps of Engineers Dredges Operating in Great Lakes

3.1.3.1 *Hoffman*

This dredge was designed by the Marine Division of the Philadelphia District, Corps of Engineers and launched from the Pusey and Jones Shipyard, Wilmington, Delaware in 1942. In 1947 she was transferred to the Buffalo District where deepening the harbors on Lake Erie has been her principal concern.



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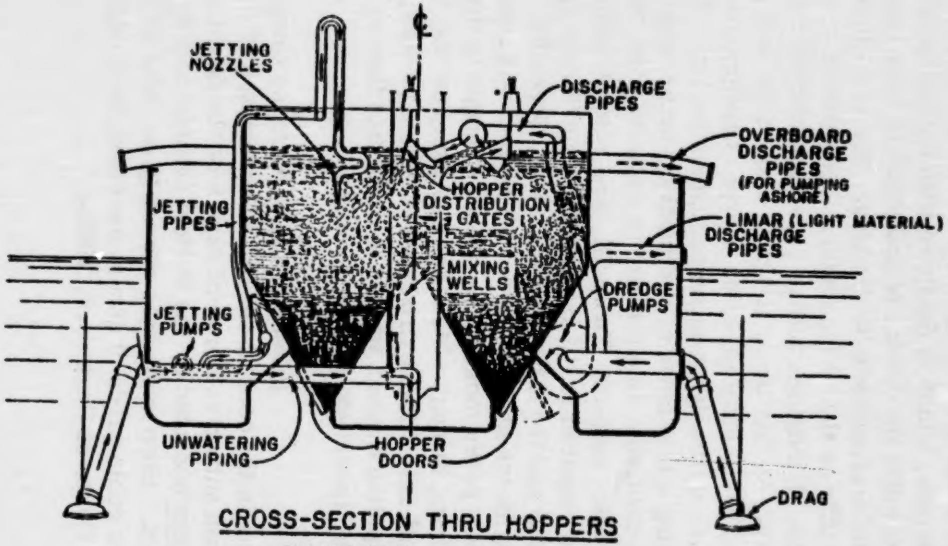

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Figure 1. OPERATIONAL SKETCH OF HOPPER DREDGE

TABLE 1

PHYSICAL CHARACTERISTICS OF THREE ARMY CORPS HOPPER DREDGES

Physical Characteristics	Lyman	Hoffman	Markham
Length, overall	215 ft. 10.5 in.	215 ft. 10.5 in.	339 ft. 6 in.
Beam	40 ft. 4 in.	40 ft. 4 in.	62 ft.
Draft, light	9 ft. 8 in.	9 ft. 8 in.	-
Draft, loaded	12 ft. 10 in.	12 ft. 10 in.	19 ft.
Displacement, loaded	2,134 long tons	2,134 long tons	7,800 tons
Hoppers	4	4	8
Hoppers, capacity	920 cu. yds.	920 cu. yds.	2,700 cu. yds.
Max. dredging depth	35 ft.	35 ft.	43.5 ft.
Total propelling power	1,400 hp.	1,400 hp.	5,200 hp.
Total pumping power	410 hp.	410 hp.	2,000 hp.
Suction pipe diameter	18 in.	18 in.	23 in.
Suction pipe length	40 ft.	60 ft.	54 ft.
Speed, light	14 mph	14 mph	17 mph
Speed, loaded	13 mph	13 mph	14 mph
Ave. Daily performance	10,000 cu. yds.	10,000 cu. yds.	30,000 cu. yds.
Crew, officers & men	43	43	54
Launched	1945	1942	1959
Height, keel to bridge	-	-	65 ft.
Bow thruster	-	-	150 hp.
Power, twin diesels	-	-	4,250 hp. each
Propellers, 4 blades	-	-	13 ft. diameter

Data source: U. S. Army Corps of Engineers, Buffalo District

1 foot = .305 meters
1 inch = .0254 meters
1 long ton = 1016 kilograms
1 cubic yard = .764 cubic meters
1 hp = 746 watts
1 mph = .045 m/sec

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Working on a vacuum cleaner principal, the *Hoffman* operates 24 hours a day, six days a week from mid-March until mid-December when lake ice prevents dredging. She is self-contained, highly mobile, and works in almost all kinds of weather. The hopper dredge is the most efficient type of dredge in areas where there is a relatively small amount of material spread over a large area and since the *Hoffman's* transfer to Buffalo many improvements in equipment and technique have greatly increased efficiency and capability. The latest improvement is a hopper pumpout system which permits the material in the hoppers to be pumped to shore disposal areas.

3.1.3.2 *Lyman*

This dredge was designed by the Marine Division of the Philadelphia District Corps of Engineers and launched from the Dravo Corporation Shipyard, Wilmington, Delaware, in 1945. In 1954 she was transferred to the Buffalo District where she performs the same duties as the *Hoffman*.

3.1.3.3 *Markham*

This dredge was designed by the Marine Division of the Philadelphia District of the Corps. The pride of the Army Engineers workhorse fleet, she was launched from Avondale Marineways Shipyard, New Orleans, Louisiana, in 1959. She was the first Army Engineer hopper dredge to sail the Internation Waterway from her training grounds in Louisiana, along the Atlantic Coast, through the Gulf of St. Lawrence and into the Great Lakes. She was commissioned in Cleveland Harbor in May of 1960 and assigned to deepening portions of the Connecting Channels in western Lake Erie. Operating like other Corps dredges, the Markham has broken all previous dredging records for any similar type vessel on the Great Lakes (U.S. Army Corps of Engineers, 1971).

3.1.3.4 *Hains*

This dredge is assigned to the Detroit District, Corps of Engineers. She is of similar vintage and design as the *Hoffman* and performs similar operations.

3.1.4 Disposal Techniques

3.1.4.1 Open Lake Disposal

Current dredge spoil disposal techniques include open water disposal, disposal in offshore diked areas, and disposal in landfills. Open water disposal includes operations that deposit spoils in inland rivers and lakes. Moreover, such disposal includes materials placed on beaches, marshes, along river edges, or any other type of unconfined land disposal in which the placed materials are subject to the being washed back into the water.

Past dredging practices in the Great Lakes involved open water disposal in the broad sense defined above. More specifically, as shown in Figures 2 through 6 the sites were chosen to be near the harbor from which the dredgings were obtained; yet in water deep enough to minimize interference with shipping. In addition, public water supply intakes and recreational beaches were avoided. The disposal areas were clearly designated and were invariably located in the nearshore waters.

3.1.4.2 Offshore and Alongshore Diked Disposal

Prior to 1967, materials from maintenance dredging in the Great Lakes were rarely deposited in diked areas to create new land. Generally, the fine sediment dredged from harbors, particularly harbors polluted with industrial wastes, seldom provides a satisfactory fill because of its hygroscopic nature and its lack of shear strength.

However, maintenance dredgings from the Rouge River at Detroit and the Maumee River in Toledo have been deposited in diked disposal areas since the 1960 and 1961, respectively. River Rouge spoil is deposited in the Grassy Island disposal area, located in the Detroit, 4.5 miles (724 meters) downstream from the lower end of the dredging project. Three separate diked enclosures are used at Toledo. Two of the areas are land disposal sites adjacent to the dredging area and the third is in Maumee Bay near the mouth of the Maumee River Estuary. Grassy Island does not provide for regular discharge of the effluent because of its large ponding area, whereas, the Toledo areas are equipped with overflows for runoff of excess water.

From 1948 to 1952, maintenance dredgings from the Cuyahoga River were deposited in the area now occupied by the Burke Lakeport Airport at Cleveland, Ohio. The City of Cleveland also placed municipal wastes in the same area. The mixed fill was found to be unsuitable as a base for the runways. It was necessary to excavate portions of the fill and replace it with suitable material.

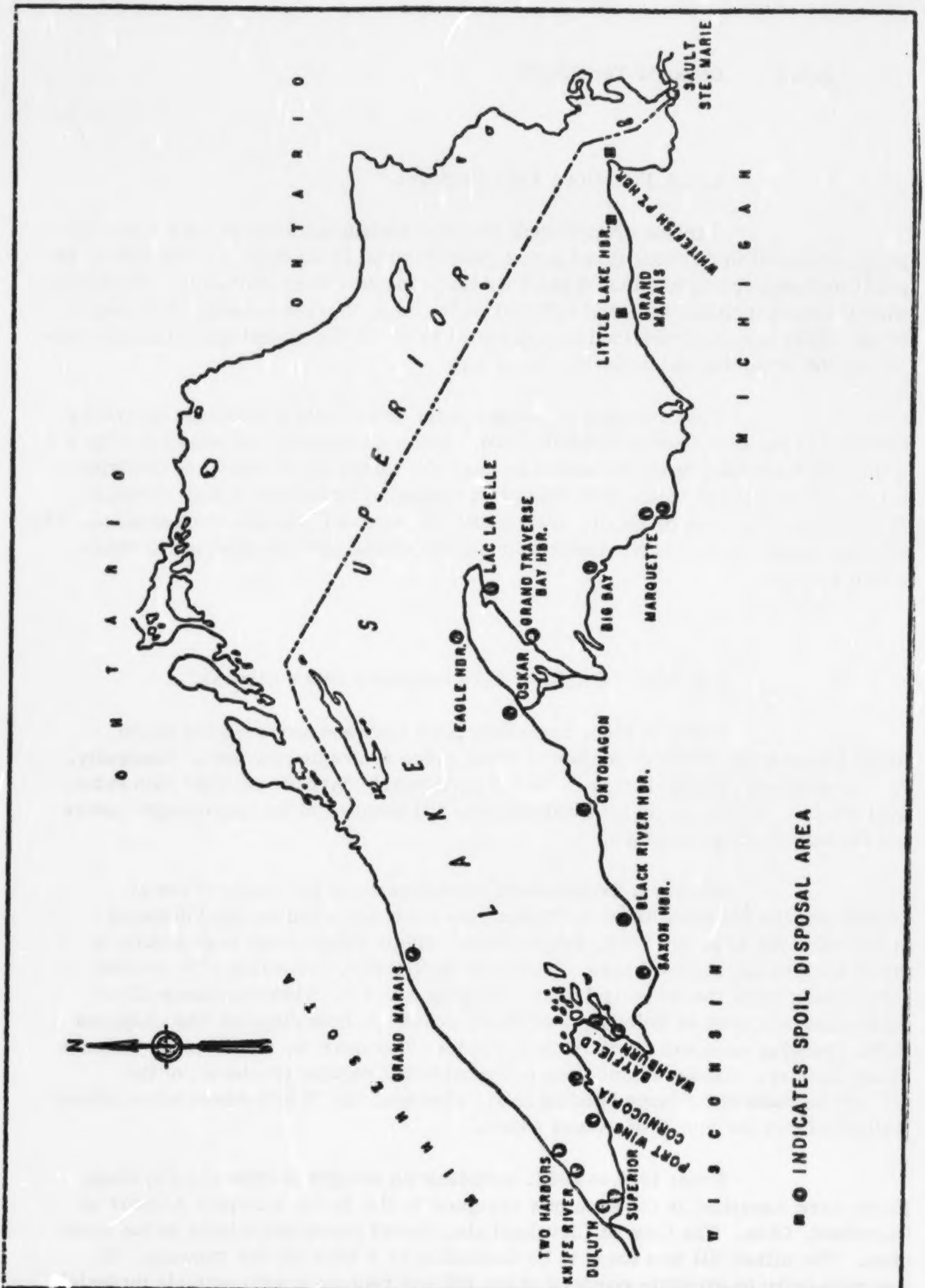

Figure 2. Disposal Areas on Lake Superior

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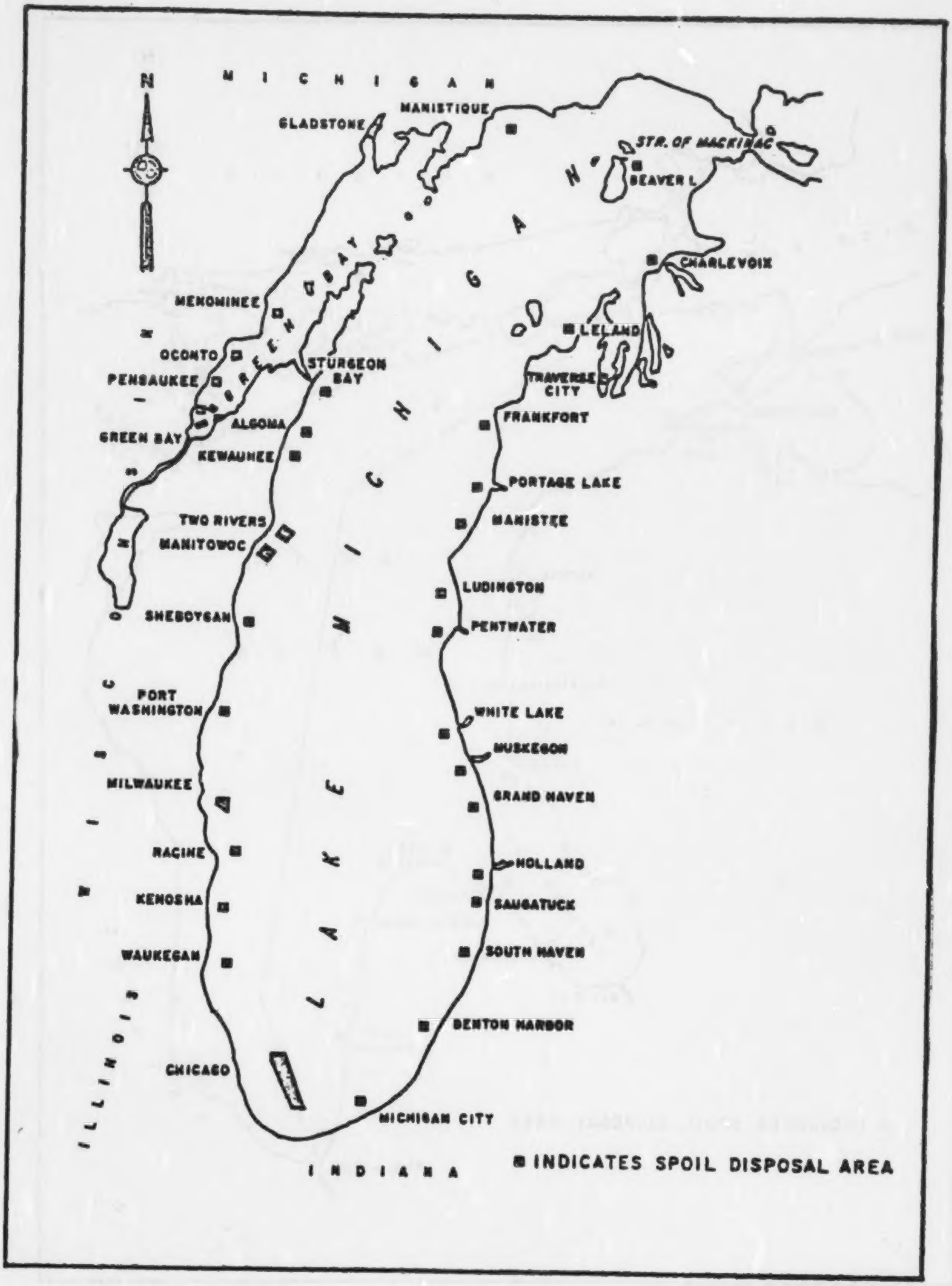
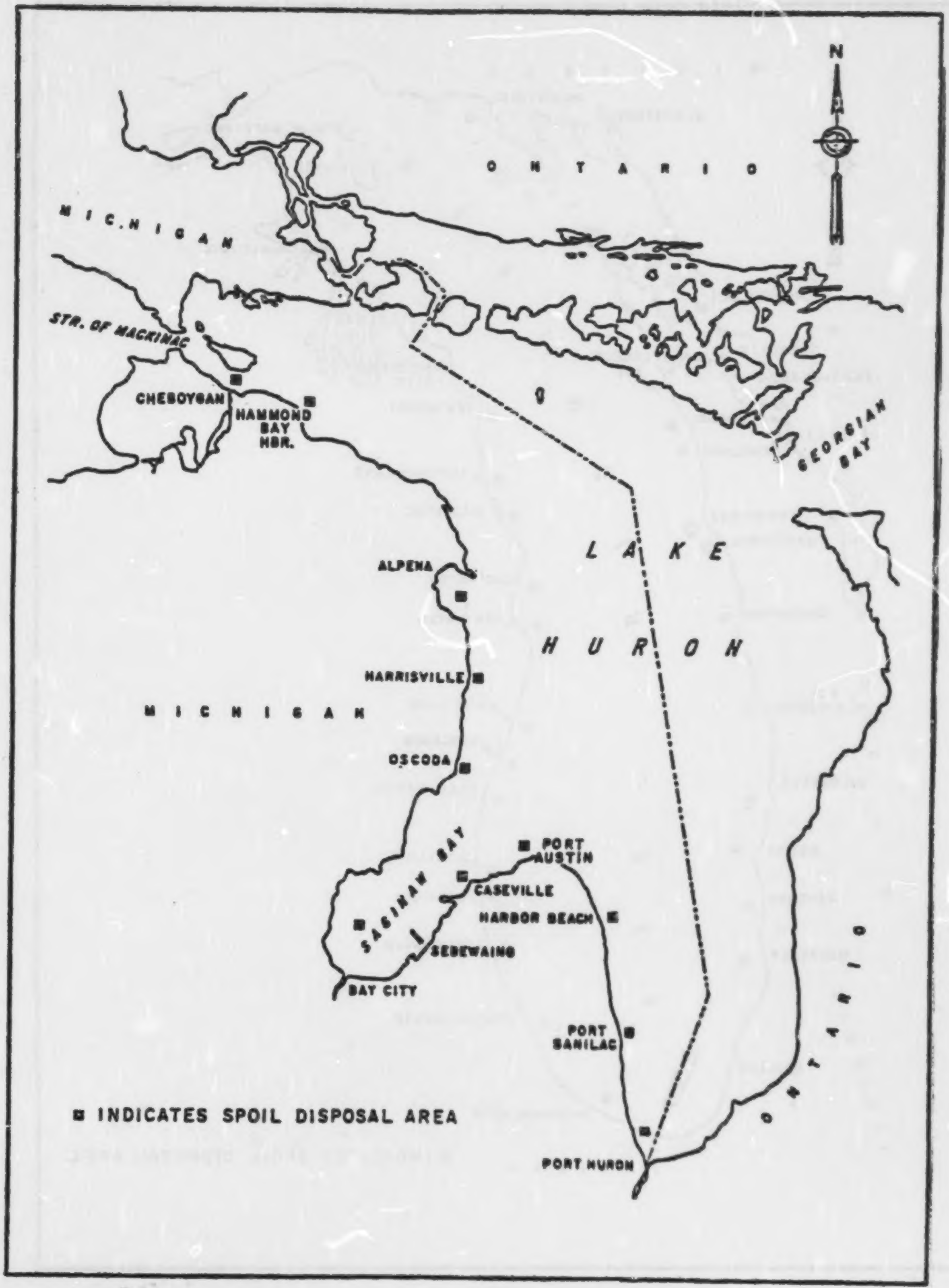


Figure 3. Disposal Areas on Lake Michigan 420<



4?1< Figure 4. Disposal Areas on Lake Huron

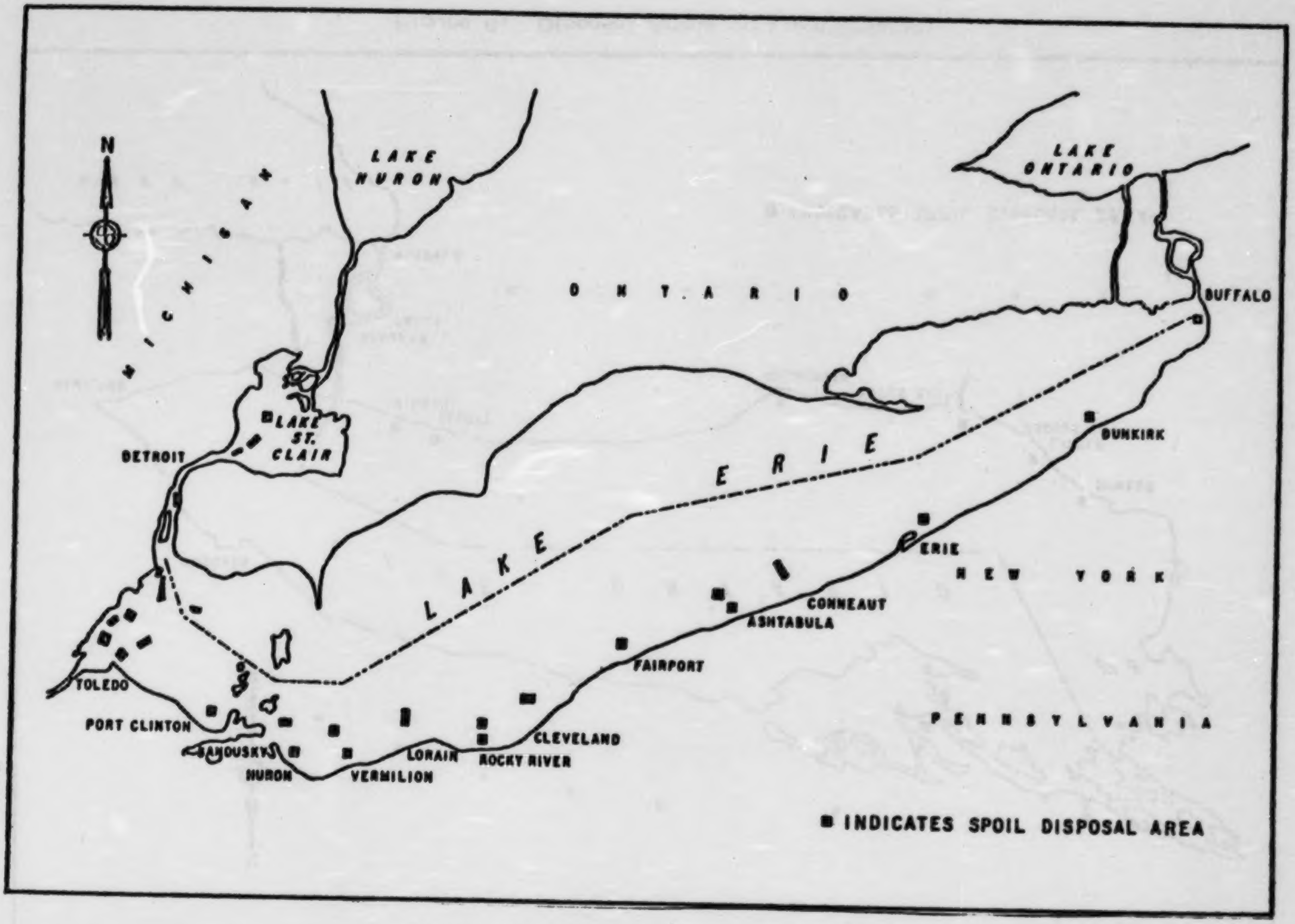


Figure 5. Disposal Areas on Lake Erie

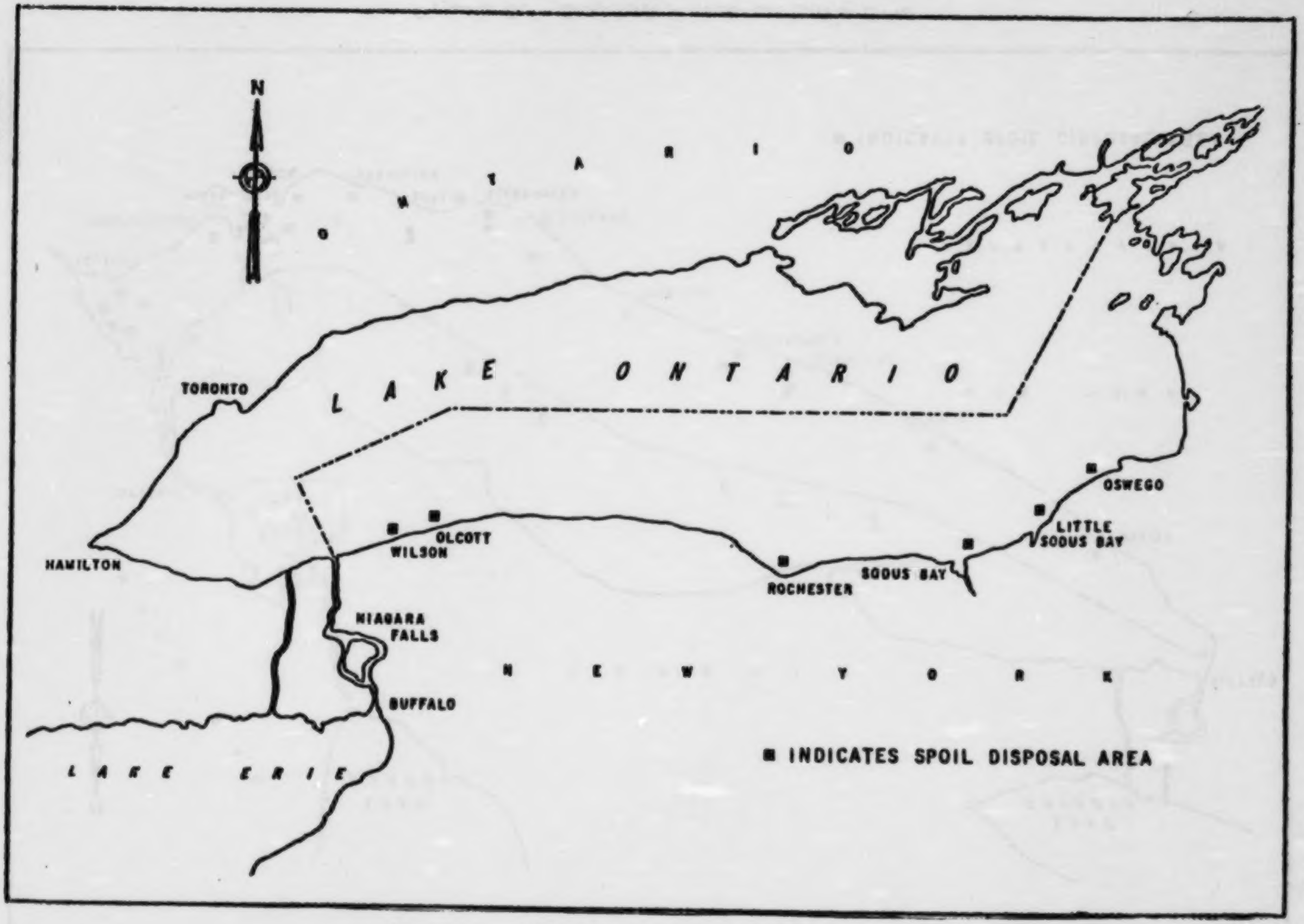


Figure 6. Disposal Areas on Lake Ontario

In 1967, as part of an experimental study by the U. S. Army Corps of Engineers (1969) alongshore diked disposal areas were constructed at Buffalo, New York, and Cleveland, Ohio, to receive portions of the maintenance dredging spoil. An existing diked area at Indiana Harbor, Indiana, was also used at the same time as part of this study.

In 1969, an offshore diked disposal area was completed in Green Bay. It is being used for new work dredgings from a project to deepen the outer channel and for disposal of maintenance dredgings from the outer sections of the channel.

3.1.4.3 Landfill Disposal

In the past, practically all landfills were constructed of new work dredgings. These materials, deposited in past geologic times, contain few man-induced wastes other than those included in recent sediments overlying the older deposits. Landfills with these dredgings usually have been suitable for beneficial uses. The U. S. Army Corps of Engineers (1969) found no record of a landfill consisting of polluted maintenance dredgings alone in the Great Lakes area.

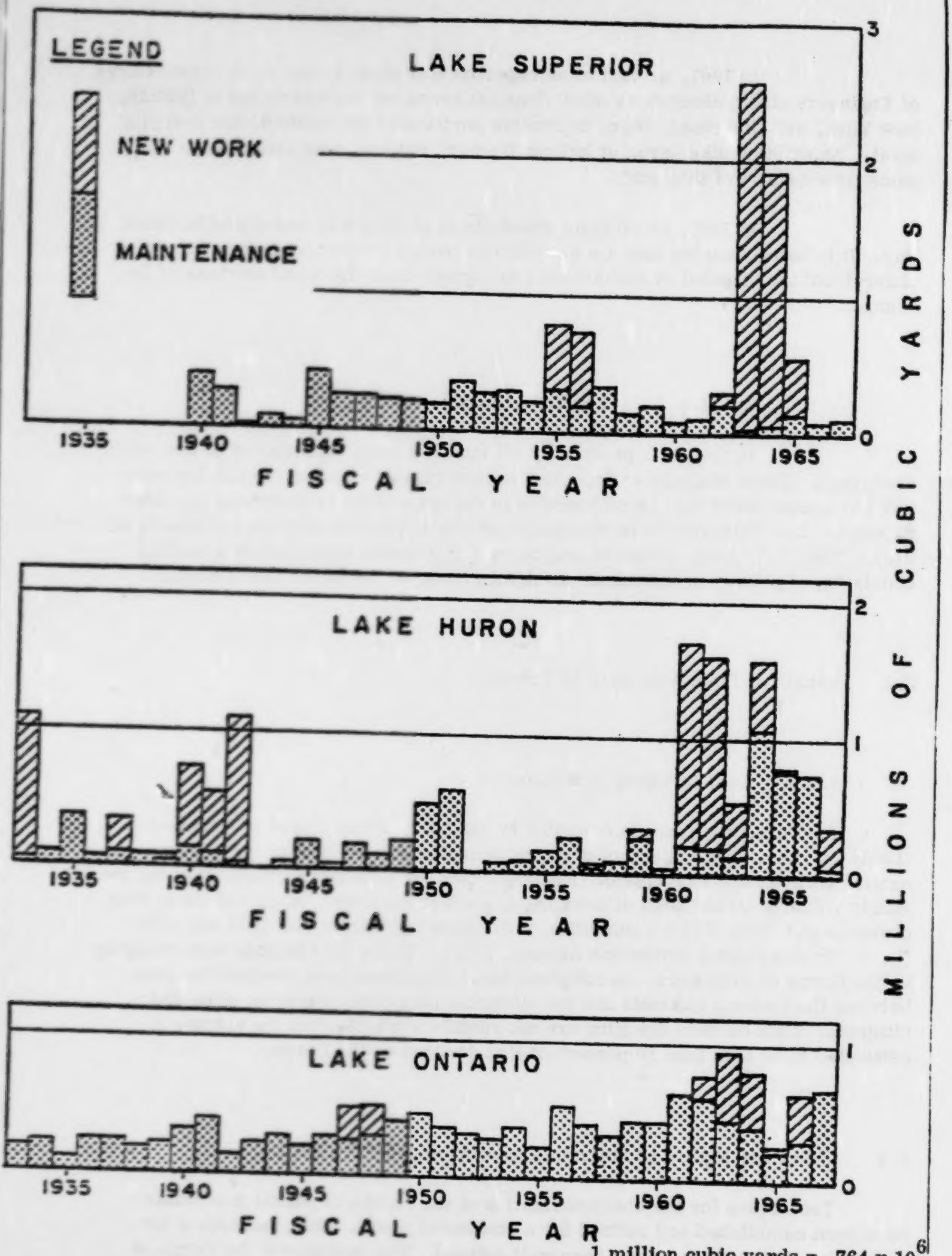
3.2 Length of Time Activities in Practice

3.2.1 Past Dredging Activities

Past dredging records compiled by the U. S. Army Corps of Engineers (1969) provide a good history of dredging operations from 1933 to the present, but earlier records are incomplete. Figures 7 through 11 are bar graphs showing the yearly volumes (1933-1968) of dredging in each of the Great Lakes and connecting channels and Table 2 gives quantities of dredgings by harbor for 1972 and 1973 (U. S. Environmental Protection Agency, 1973). These data include only dredging by the Corps of Engineers. In addition, local industries have dredged the area between the Federal channels and the unloading piers and in private slips and channels. Data on such dredging are not readily available, but the volume is estimated to be less than 10 percent of that dredged by the Corps.

3.3 Types and Nature of Pollutants Associated with Dredging

Techniques for the characterization of the degree of pollution of water have been established and refined for a number of years. Such techniques for sediments, however, have not been well defined. The practice of the Corps of



1 million cubic yards = .764 x 10^6 cubic meters

Figure 7. Dredging in Lakes Superior, Huron and Ontario By Corps of Engineers

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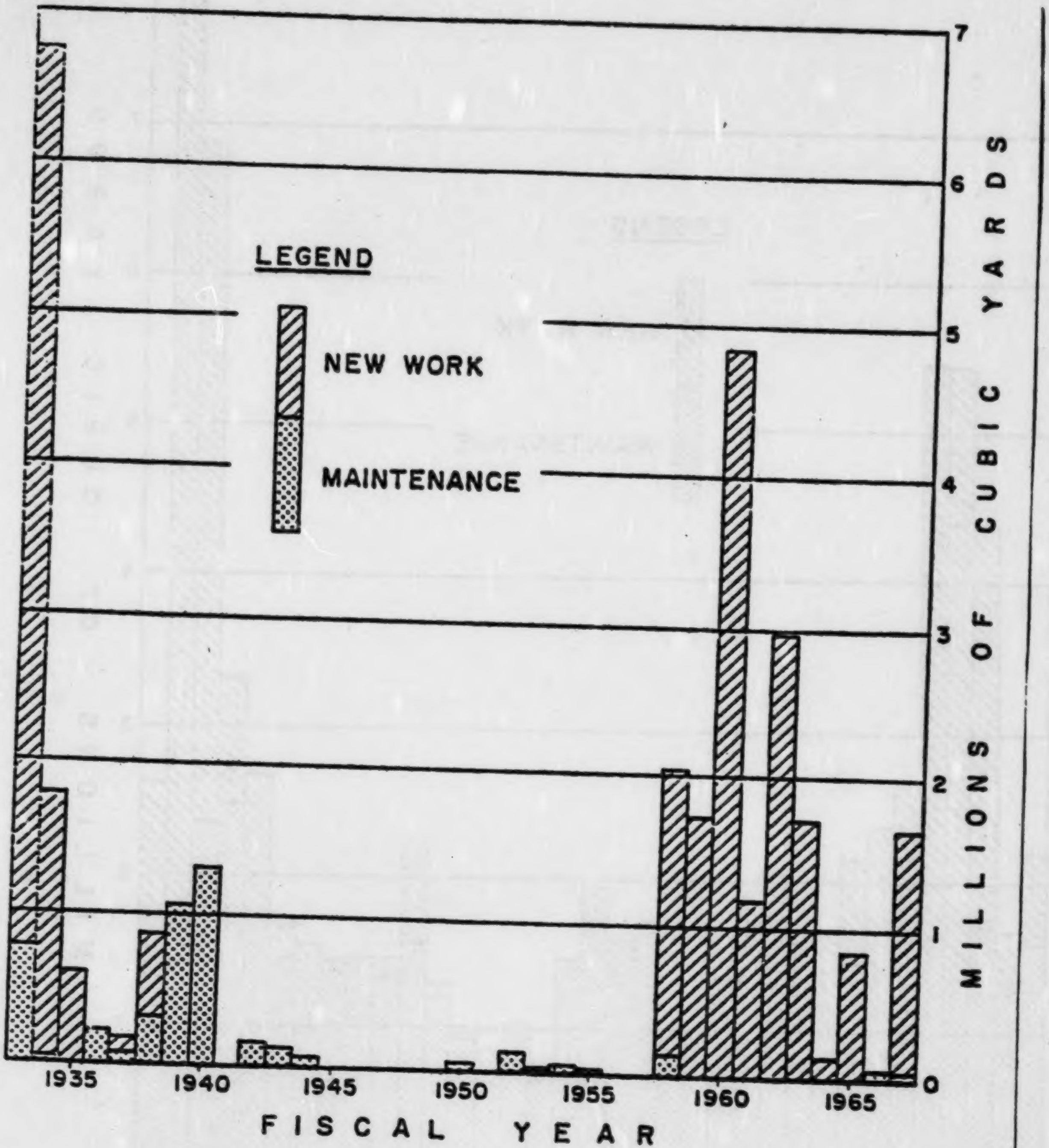
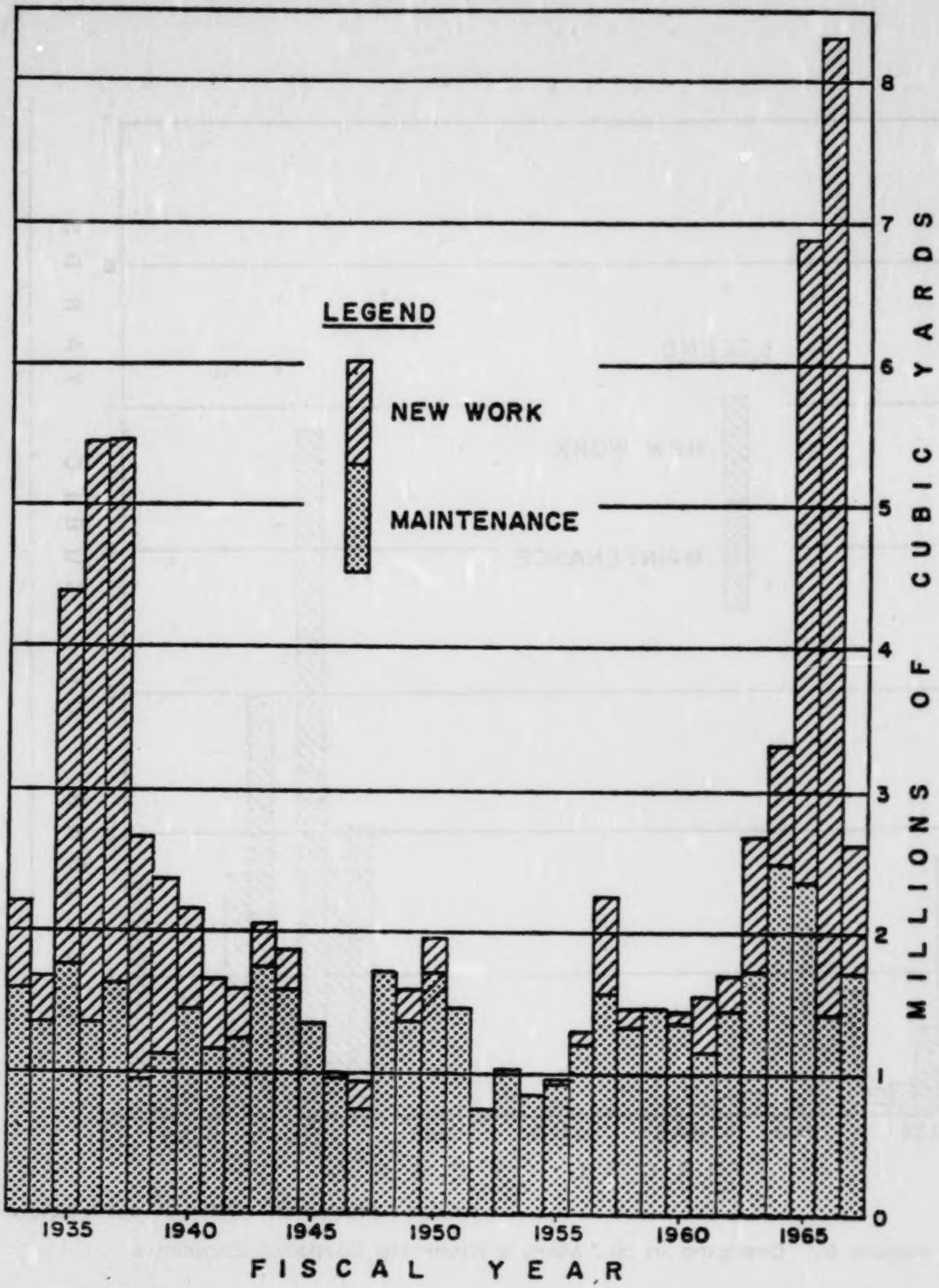


1 million cubic yards = .764 x 10^6 cubic meters

Figure 8. Dredging in St. Mary's River By Corps of Engineers

426<



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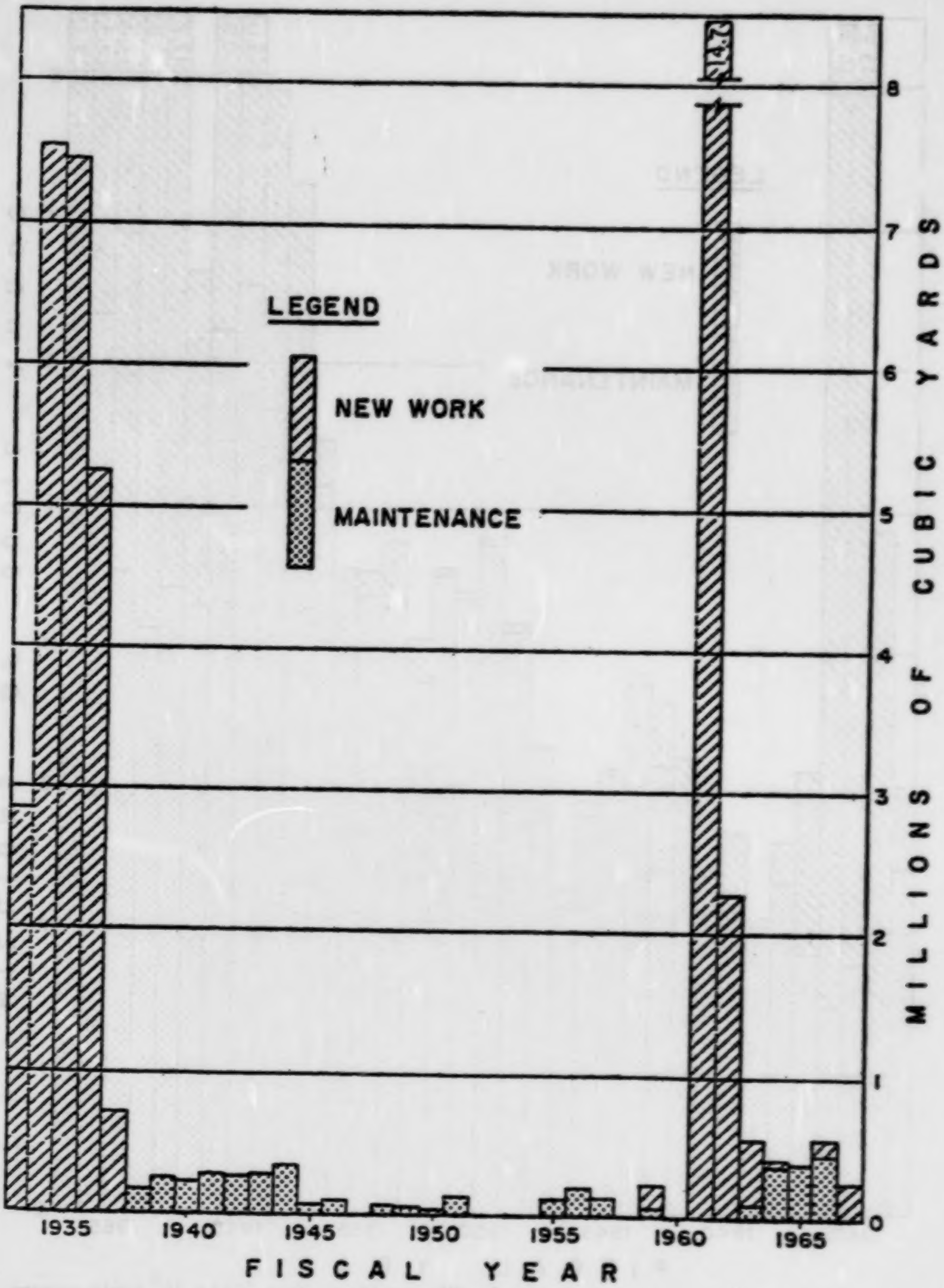
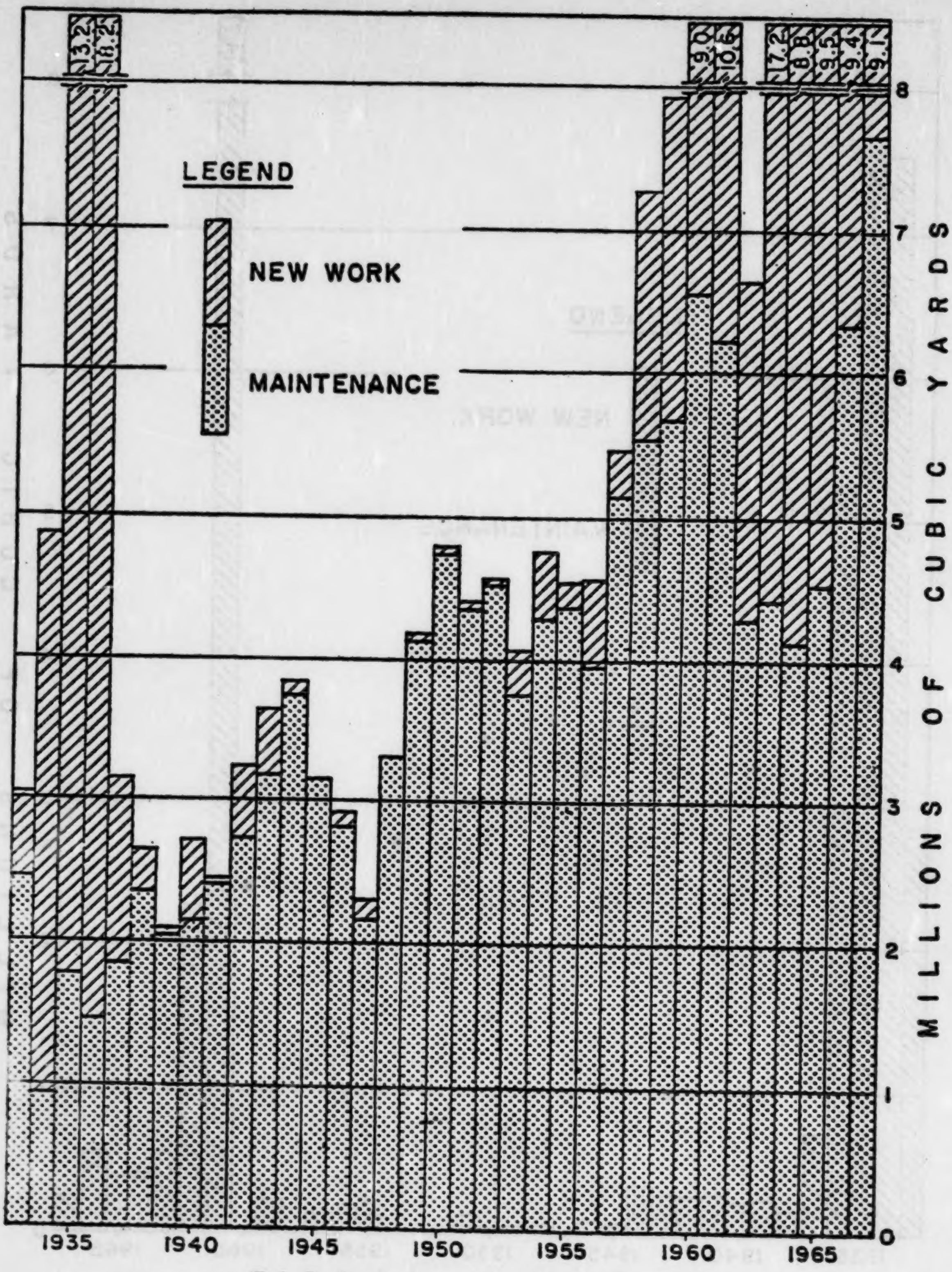
1 million cubic yards = .764 x 10^6 cubic meters

Figure 9. Dredging in Lake Michigan By Corps of Engineers



1 million cubic yards = .764 x 10^6 cubic meters

Figure 10. Dredging in Lake St. Clair and St. Clair River By Corps of Engineers



1 million cubic yards = .764 x 10^6 cubic meters

Figure 11. Dredging in Lake Erie and Lower Detroit River Including Rouge River By Corps of Engineers

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TABLE 2

QUANTITY OF MATERIAL DREDGED FROM GREAT LAKES HARBORS AND METHODS OF DISPOSAL DURING FISCAL YEARS 1972 AND 1973

Units in cubic yards (0.764 cubic meters)

Harbor	FY 1972			FY 1973		
	On Land	Open Water	Total	On Land	Open Water	Total
Arcadia	–	–	0	13,000	–	13,000
Au Sable	–	41,675	41,675	–	7,420	7,420
Charlevoix	–	5,200	5,200	–	–	0
Frankfort	–	30,191	30,191	–	23,132	23,132
Grand Haven	–	79,094	79,094	56,742	28,993	85,735
Grand Morais	–	–	0	–	60,000	60,000
Grand River	44,378	–	44,378	41,000	–	41,000
Harrisville	–	25,950	25,950	–	–	0
Holland	68,519	10,695	79,214	60,000	44,600	104,600
Inalnd Route	76,259	–	76,259	–	–	0
Leland	–	18,600	18,600	–	24,400	24,400
Little Lake	–	37,305	37,305	–	34,525	34,525
Ludington	–	24,742	24,742	–	33,230	33,230
Manistee	–	42,969	42,969	7,440	24,593	32,033
Monroe	127,260	–	127,260	136,229	–	136,229
Muskegan	–	55,009	55,009	–	54,000	54,000
Pentwater	–	37,010	37,010	–	35,000	35,000
Portage Lake	–	–	0	–	48,150	48,150
Rouge River	135,322	–	135,322	151,504	–	151,504
Saugatuck	–	41,980	41,980	–	37,100	37,100
Saginaw	86,944	–	86,944	87,943	69,262	157,205
South Haven	16,178	6,789	22,967	3,762	37,754	41,516
St. Clair River	–	26,337	26,337	–	8,800	8,800
St. Joseph	42,269	10,003	52,272	8,012	39,792	47,804
St. Mary's River	–	122,011	122,011		40,123	40,123
Toledo	1,273,181	103,841	1,377,022	513,013	165,611	678,692
Whitefish	–	23,327	23,327	–	33,500	33,500

Data Source: U. S. Environmental Protection Agency (1973)

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Engineers has been to base classifications of degree of pollution on field techniques of an observational nature. Parameters used include odor, color, particle size, and benthic fauna.

More recently, research has been undertaken to study the feasibility of using more refined laboratory techniques involving such parameters as total and soluble phosphate, nitrogen, biochemical oxygen demand (BOD), chemical oxygen (COD), oil and grease, chloride, iron, pH, alkalinity, Eh, total and fecal coliforms, and benthic organisms.

Currently (August, 1974) assessment of degree of pollution of harbor sediments is determined by the Environmental Protection Agency. EPA designates materials as polluted or unpolluted based on volatile solids, COD, nitrogen, oil and grease, mercury, lead, and zinc (see Table 3). The Corps of Engineers then contracts to an environmental consultant to study the polluted areas more closely. A confined facility is then designed to contain the polluted spoil material.

The determination of the degree of pollution of sediments and dredge materials is much more complicated than determining the degree of pollution of water for two reasons:

1. Stratification. Sediments, being solids, are much less mobil than water and therefore occur in a highly heterogeneous spacial distribution. Thus obtaining a "representative" sample is difficult if not impossible. This increases the number of analyses required to properly characterize the materials.

2. Digestibility. The soil constituents of sediments represent the most resistant of the natural materials. This complicates analytical procedures which require the digestion of the material to be analyzed.

3.4 State-of-the-art in Assessing and Quantifying Problems

Sediments become polluted before, during, and after transport into harbors. In general, the sources of pollution can be categorized as municipal, industrial, and agricultural. Agricultural pollution derives from animal wastes and from the use of fertilizers and pesticides whose residues are washed or leached into streams and other drainage channels. Some contamination of sediments and water must be ascribed to municipal wastewaters that are emptied into receiving waters as stormwater discharges, overflows of combined sewers, spillage from surcharged and broken sewers, and effluents from sewage treatment plants. Industrial wastewaters may be added along with municipal sewage or directly through industrial outfalls.

Table 3

EPA Limits for Polluted Material

Component	Conc. % (dry weight basis)
Volatile solids	6.0
Total kjeldahl nitrogen (TKN)	0.10
Oil and Grease	0.15
Mercury	0.0001
Lead	0.005
Zinc	0.005
COD	5.0

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Little is known about the ability of sediments to sorb and hold specific pollutants except for recent work on the sorption of phosphorus and nitrogen on particulate matter. While phosphorus commonly exists in solution in different ionic forms, direct precipitation of phosphatic salts is probably of little importance as a mechanism for their removal in nature. However, removal of phosphorus by sorption appears to be a significant mechanism, with clay minerals, limestone, dolomite, and iron all having capacities to remove phosphatic salts from solution. Experiments have shown that sediments have a great capacity to absorb phosphorus, but to date the mechanics of anionic sorption have not been fully identified. Total nitrogen in a stream is the sum of nitrogen occurring as ammonia, nitrite, nitrate, and organic nitrogen. Fifty to ninety percent of the total nitrogen probably is precipitated as organic particles or sorbed on sediments as molecules. Ammonia (NH_3) is electrically neutral, but is a highly polar molecule, and is capable of being adsorbed on clay. Nitrite (NO_2^-) and nitrate (NO_3^-) may be transported by anionic sorption mechanisms, but they probably are transported as sorbed organic nitrogen compounds or as nitrogen in discrete organic particles (U. S. Army Corps of Engineers, 1969).

For the most part, sediments from upstream sources are deposited in river channels and inner harbors. In addition, sand is piled against the windward side of breakwalls by littoral drifts. During storm conditions, wind and wave action blow and wash sand particles over the breakwalls and into the relatively calm waters or the harbor, where they settle as shoals. These sediments are susceptible to pollution by watercraft in the harbors and waterways, as well as from municipal and industrial discharges.

The U.S. Environmental Protection Agency (1973) has identified the Great Lakes harbors containing major areas of polluted sediments. These harbors are listed in Table 4 and shown for each lake on Figures 12 through 16.

3.5 Mobility of Pollutants within the System

The environmental impact of dredge disposal are principally concerned with direct and indirect effects on biological communities. The benthic communities are most directly affected. New work projects pose the most serious threat to benthic communities since they perturb areas whose biological development may be quite mature. Conversely, maintenance dredging has less effect because recolonization has progressed only since the previous dredging activities. The direct affects in either case are limited to the immediate area of dredging.

The indirect effects of dredging may have both detrimental and beneficial effects on the biological community. The effects may be of either a physical or chemical nature, though physical effects are most common in the dredging

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TABLE 4

GREAT LAKES HARBORS FOUND TO CONTAIN POLLUTED SEDIMENTS

LAKE SUPERIOR	Whitefish Harbor (northernmost 20 percent of area)
LAKE MICHIGAN	Frankfort Harbor (area in Lake Betsie)
	Grand Haven (from junction upstream)
	Holland Harbor (inner section, upper 33 percent of channel)
	South Haven Harbor (upper 33 percent of channel)
	St. Joseph Harbor (from C & O R. R. upstream, upper 50 percent)
	Traverse City Harbor (all)
LAKE HURON	Alpena Harbor (all)
	Bay Port Harbor (all)
	Caseville Harbor (from shoreline upstream)
	Clinton River Harbor (from turning basin disposal area upstream)
	Harbor Beach Harbor (all)
	Inland Route and Crooked River Channel (all)
	Lake St. Clair (all)
	Les Chenneaux Island Channel (all)
	Port Austin Harbor (33 percent of basin nearest to shore)
	Port Sanilac Harbor (all)
	Saginaw River (to point 6.5 miles off shore)
	Sebewaing River (from mouth outward)
LAKE ERIE	Bolles Harbor (all)
	Detroit River (east and west outer channel, lower Livingstone channel, lower 67 percent of Trenton channel and lower 50 percent of Amherstburg channel)
	Monroe Harbor (all)
	Port Clinton (all)
	Rouge River (all)
	Toledo (to 5 miles offshore)
LAKE ONTARIO	None

Data Source: U. S. Environmental Protection Agency (1973)
1 mile = 1609 meters

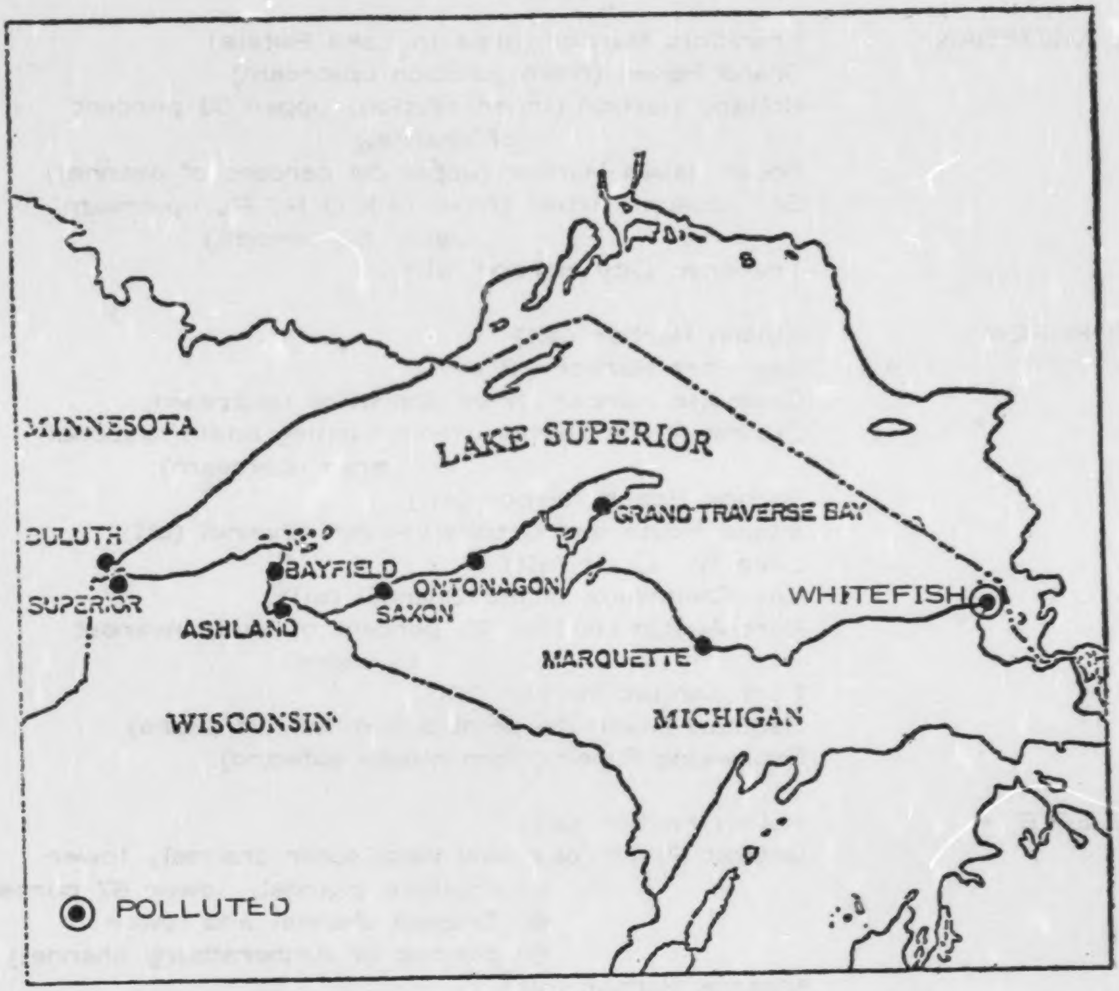

Figure 12. Polluted Harbors on Lake Superior

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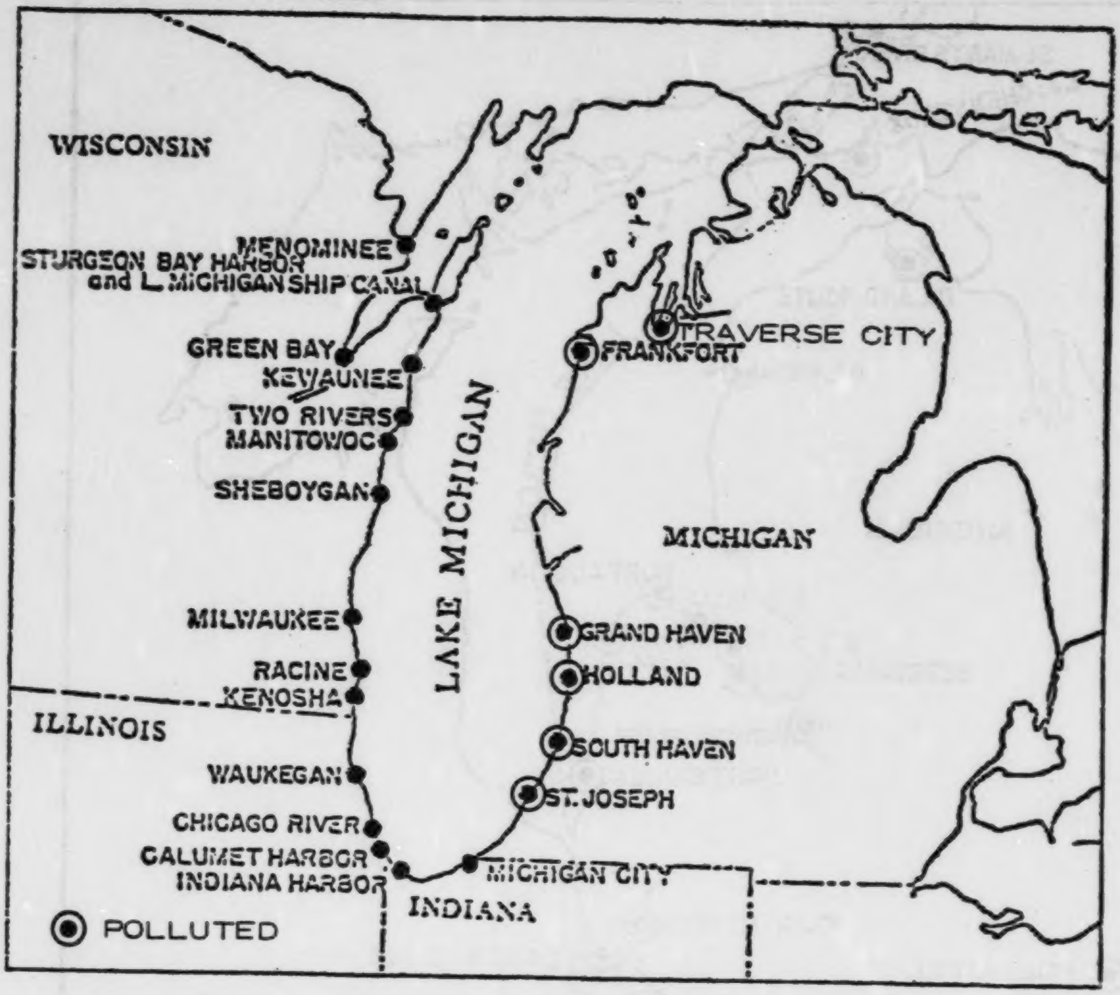

Figure 13. Polluted Harbors on Lake Michigan

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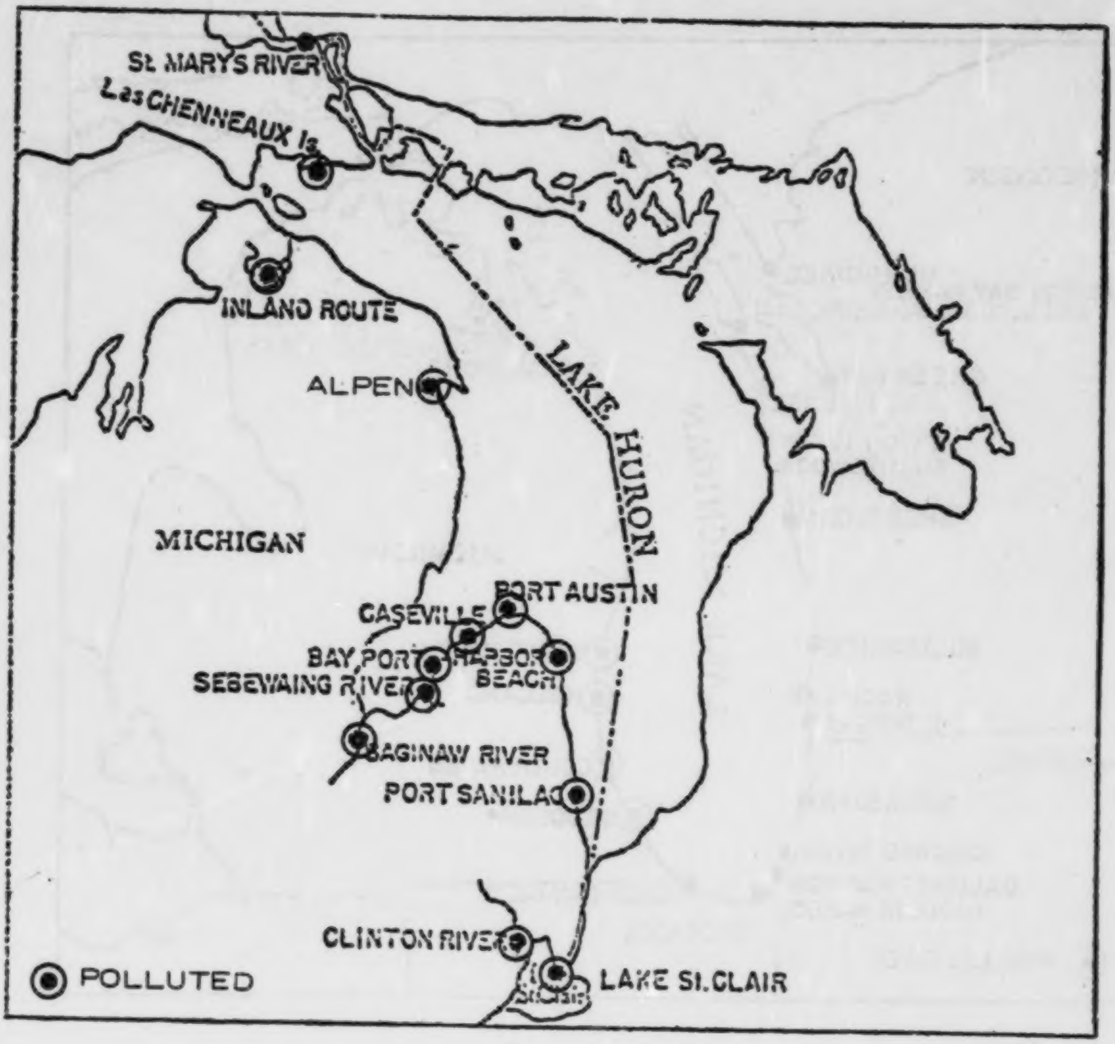

Figure 14. Polluted Harbors on Lake Huron

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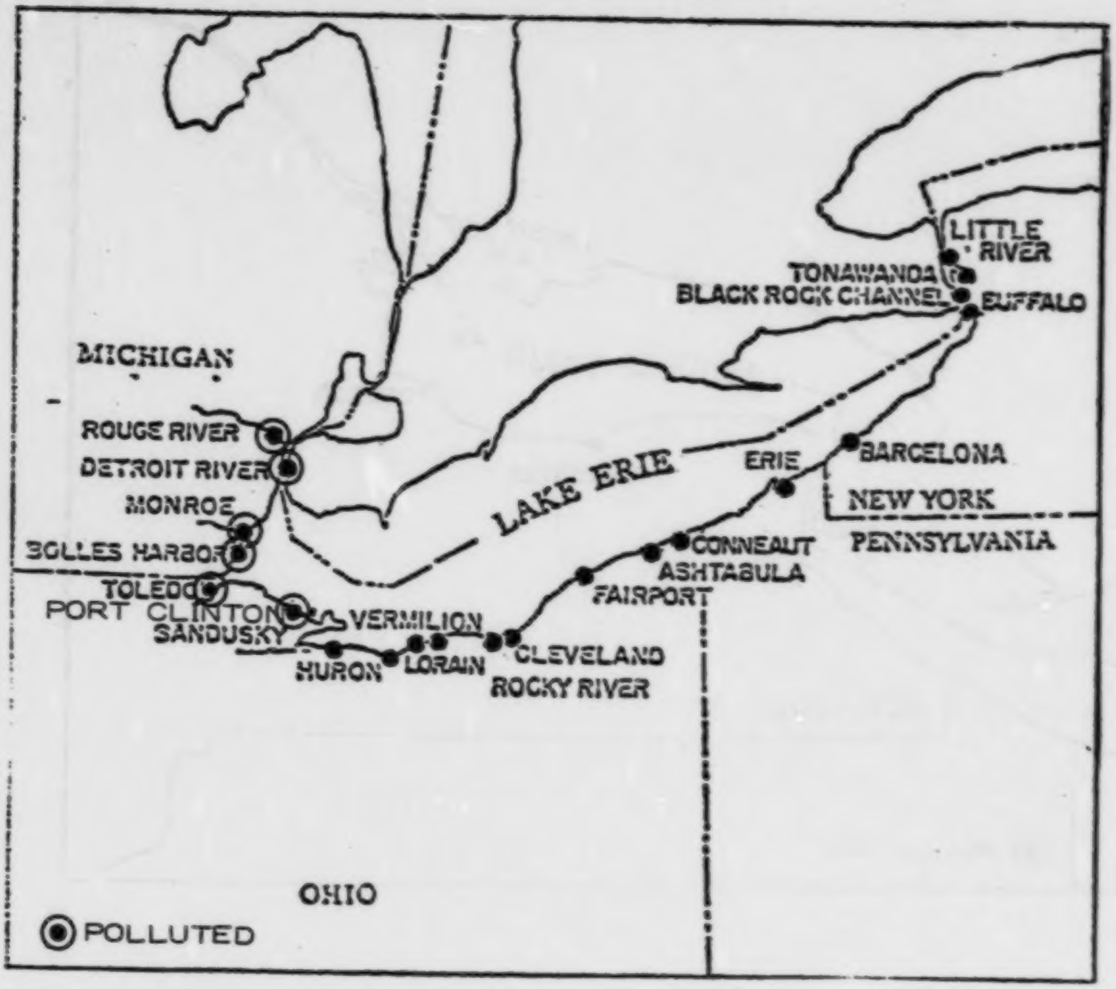

Figure 15. Polluted Harbors on Lake Erie

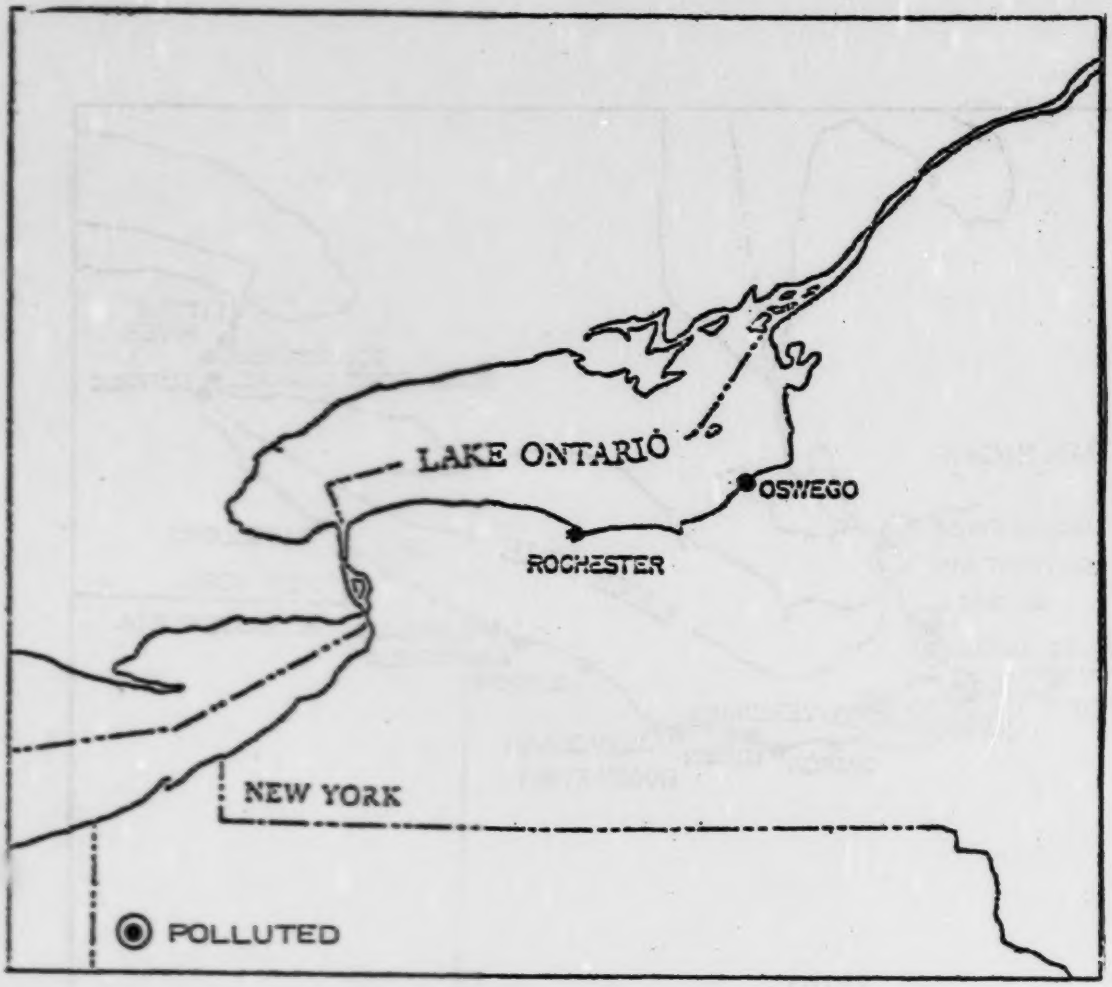

Figure 16. Polluted Harbors on Lake Ontario

operation. Physical alterations include changing of the geometry of the bottom and, in general, creating deeper water. The nature of the substrate will be altered if different geologic strata are encountered. These alterations may in turn result in changes in water velocity and current patterns and in changes in future distribution patterns of sediments. In addition the nature of the sediment-water interface will be changed and disequilibrium may be imposed between concentrations of pollutants in the water and in the sediment.

The type and degree of physical alteration depends upon the dredging method used. In suction dredging loose materials are removed from previously dredged areas. This type of dredging is thought to be the least harmful to the biological community. Mechanical-suction dredging employing cutterhead dredges is most likely to harm the biological community. In addition to changing the bottom geometry, the dredges create considerable turbidity in the immediate vicinity of the dredge. This suspended material may then be more susceptible to release of pollutants into the water.

The environmental effects of disposal of dredge spoil may be either physical or chemical in nature. Short-term effects include increased turbidity, sediment buildup, and depletion of oxygen. In addition to being unsightly, turbidity can reduce light penetration, flocculate algae and decrease the availability of food. Sediment buildup can destroy spawning areas, smother benthic organisms, destroy bottom habitats and habitat diversity, reduce food supply and reduce vegetation coverage. Oxygen depletion can suffocate organisms and release pollutants because of anaerobic conditions.

Because these actions are immediate, their effects are strongly determined by the specific manner by which the dredge spoil is returned to the water. The duration of spoil-water contact and the degree of dispersion of the spoil are important parameters in determining short-term effects. Hopper dredges and barges using dump disposal while keeping the vessel stationary minimize both dispersion and spoil-water contact time. Conversely, sediment buildup is high and rapid, though confined to a relatively small area. Pipeline and side caster disposal techniques maximize the dispersion and spoil-water contact time.

Irrespective of the disposal technique used, the duration and extent of short-term effects will be highly dependent on water depth, current velocities and patterns, bottom configuration of the disposal area and the grain size of the materials disposed. Coarse materials in shallow, still water overlying flat bottoms will have minimum dispersion and spoil-water contact time. Conversely, fine grained soil in deep water with high currents overlying sloping bottoms will maximize dispersion and spoil-water contact time.

Long-term effects of dredge disposal are, of course, more varied, and tend to be indirect. Many complex mechanisms can be postulated, but scientific verification is difficult to obtain because of the time involved and because of the difficulty in isolating cause and effect relationships. The highest potential for detrimental effects results when polluted dredge spoil is disposed of in unpolluted areas. There will be a tendency for pollutants to move out into the less polluted environs. However, this diffusion is time dependent; hence long-term effects result. This is particularly important in the cases of nutrients and toxins. The processes involve chain reactions and determining release times becomes difficult. The rate of release is influenced by three factors (Moore and Silver, 1973):

1. the time rate for a given process step,
2. the quantity of material transformed in the process, and
3. the distance of transfer involved in the process.

These factors, combined with the numberous possibilities for branching, result in extremely complex process networks for release of pollutants.

3.6 Natural Renovation Mechanisms

The use of the absorptive capacity of sediments to attenuate pollutants is often looked to as a natural renovation mechanism. Because of their high physicochemical activity, soils and their associated biological constituents can detain large amounts of pollutants. This detention capacity is represented by a partition coefficient giving the ratio of the concentration of a pollutant in the sediment to the concentration of that pollutant in the surrounding water. This partition coefficient may be of the order of 10,000 = 1. However, it is important to note that the detention process is reversible, and as less polluted water occupies the lakes, the sediment will return pollutants back to the water. Thus while sediments perform a significant role in detaining pollutants, they probably do not serve as permanent sinks.

3.7 Probable Future Activities

Estimates of future annual maintenance dredging requirements are difficult to make because of the variations in the present quantities dredged. Also, it is expected that current efforts by regulatory agencies may result in a reduction in the volume of waste discharges which now end up as harbor sediments. While the volume of such discharges is large, it is generally only a small fraction of the dredging volume. Increased soil conservation practices may reduce the amount of sediment originating from soil erosion, but, up to the present, such practices have been implemented only at small watersheds. Table 5 shows the U. S. Army Corps of Engineers (1969) estimates for future annual maintenance dredging for the various harbors currently maintained by the Corps. The tabulated values do not reflect any reductions which may result from the aforementioned control measures.

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TABLE 5

ESTIMATED QUANTITIES OF FUTURE ANNUAL MAINTENANCE DREDGING

Lake or Connecting Channel	Name of Harbor or River Project	Future Annual Maintenance Dredging in 1,000 Cu. Yds. 1 cubic yard = .764 cubic meters
Lake Ontario	Great Sodus Bay Harbor	40
	Oswego Harbor	80
	Rochester Harbor	360
	Other small projects	nil
		480
Lake Erie, Niagara and Detroit Rivers	Ashtabula Harbor	220
	Black Rock Channel & Tonawanda Harbor	100
	Buffalo Harbor	525
	Cleveland Harbor	1,220
	Conneaut Harbor	100
	Detroit River	800
	Dunkirk Harbor	20
	Erie Harbor	300
	Fairport Harbor	400
	Huron Harbor	200
	Lorain Harbor	300
	Monroe Harbor	240
	Rouge River	300
	Sandusky Harbor	600
	Toledo Harbor	1,400
	Other small projects	35
		6,760
Lake Huron, St. Mary's River	Au Sable Harbor	40
	Harbor Beach	30
	Saginaw River	600
	St. Mary's River	250
	Other small projects	100
		1,020

TABLE 5 (Con't.)

Lake or Connecting Channel	Name of Harbor or River Project	Future Annual Maintenance Dredging in 1,000 Cu. Yds. 1 cubic yard = .764 cubic meters
Lake Michigan	Calumet Harbor and River	200
	Chicago Harbor and River	108
	Charlevoix Harbor	30
	Frankfort Harbor	32
	Grand Haven Harbor and River	100
	Green Bay Harbor	137
	Holland Harbor	105
	Indiana Harbor	151
	Kenosha Harbor	29
	Kewaunee Harbor	28
	Ludington Harbor	55
	Manistee Harbor	55
	Manistique Harbor	40
	Manitowoc Harbor	35
	Michigan City Harbor	48
	Milwaukee Harbor	70
	Muskegon Harbor	105
	Pentwater Harbor	70
	Portage Lake Harbor	40
	Racine Harbor	30
	Saugatuck Harbor	55
	Sheboygan Harbor	23
	South Haven Harbor	74
	St. Joseph Harbor	80
	Two Rivers Harbor	51
	Waukegan Harbor	32
	White Lake Harbor	60
	Other small projects	37
		1,880
Lake Superior	Duluth-Superior Harbor	150
	Ontonagen Harbor	80
	Keweenaw Waterway	40
		270

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TABLE 5 (Con't.)

Lake or Connecting Channel	Name of Harbor or River Project	Future Annual Maintenance Dredging in 1,000 Cu. Yds. 1 cubic yard = 764 cubic meters
Lake St. Clair, St. Clair River	Clinton River	20
	Lake St. Clair	200
	St. Clair River	200
	Other small projects	7
		427
	Total	10,837

Data Source: U. S. Army Corps of Engineers (1969)

At present, it is unlikely that further deepening of harbors and connecting channels by new work dredging will occur in the near future. Almost all major harbors are now improved to accomodate the size of vessel which can pass through the ship locks on the St. Lawrence River, the Welland Canal or the St. Mary's River. The new Poe Lock, completed in 1968 at Sault Ste. Marie, Michigan, can pass vessels larger than any now navigating the Great Lakes. Under study at the present time are proposals to construct additional locks on the St. Lawrence River and new canals linking Lakes Ontario and Erie to relieve congestion and provide capacity for additional shipping. These projects, if authorized and constructed, are likely to include ship locks of larger size than those now available. Vessels larger than those now in use are being planned, and there will be a growing demand for deeper and larger harbors.

For the immediate future, sites are being planned or are under study for Saginaw Bay, Toledo-Monroe, Pt. Mouille, Dickinson Island, Holland Bay, Alpena, Frankfort, Port Sanilac, Harbor Beach, Bay Port, Clinton River, Whitefish Point, Sebewaing, Monroe, South Haven and Cuseville (EPA, 1973).

3.8 Projected Seriousness of Future Pollution

The projected future activities indicate that the Corps of Engineers will continue to dredge of the order of 10 million cubic yards (7.6 million cubic meters) per year. In all likelihood, there will be an increase in the percentage of polluted sediments and, therefore, an increase in the requirements for diked disposal. Thus there exists an increased potential for nearshore water pollution if the spoils are not properly handled. Conversely, if proper technology is applied to controlling pollutant loss from such diked disposal areas, the pollution potential may be greatly reduced.

3.9 Institutional Arrangements to Regulate Dredging

The United States Environmental Protection Agency is the only governmental agency within the Great Lakes Basin that has any direct legislative control over pollution caused by dredging activities. They derive this control from the following two pieces of federal legislation:

1. Section 123 of Public Law 91-611, The River and Harbors Act of 1970, which is concerned with all aspects of diked disposal systems in the Great Lakes Basin, and

2. Section 404 of Public Law 92-500, The Water Pollution Control Act Amendments of 1972, which requires that a permit be issued for the deposition of any dredged material in the nation's waters.

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As mentioned in Section 3.3 of this Report, the Environmental Protection Agency has established criteria for seven parameters that are associated with the material to be dredged. Under their regulations, if the levels of the established criteria are exceeded for any of these parameters, the material to be dredged is considered to be polluted. This material may not be disposed of in open waters, but must be disposed of in a diked system.

The States within the Great Lakes Basin have not established any regulations specifically directed toward controlling pollution from dredged materials. However, all the States feel that they can take action to control pollution from dredging operations under the general provisions of their water quality laws.

Section 4

SUMMARY OF RELEVANT ONGOING OR PROPOSED RESEARCH, DEMONSTRATION OR MONITORING PROGRAMS

4.1 Research Applicable to All Geographic Regions

The River and Harbor Act of 1970 (Federal Public Law 91-611, December 31, 1970; Section 123 (i)) authorizes the Corps of Engineers to undertake the following research:

> "The Chief of Engineers, under the direction of the Secretary of the Army, is hereby authorized to extend to all navigable waters, connecting channels, tributary streams, other waters of the United States and waters contiguous to the United States, a comprehensive program of research, study and experimentation relating to dredged spoil. This program shall be carried out in cooperation with other Federal and State agencies, and shall include, but not be limited to, investigations on the characteristics of dredged spoil, and alternative methods of its disposal. To the extent that such study shall include the effects of such dredge spoil on water quality, the facilities and personnel of the Environmental Protection Agency shall be utilized."

The U. S. Army Engineer Waterways Experiment Station was assigned to implement the program in consultation with the EPA and other federal and state agencies. The program is supervised by the office of Dredged Material Research through their Dredged Material Research Program. Table 6 presents the recommended $30 million research program to be undertaken in FY 73 through FY 77. A status report current as of February 1974 is given in Figure 17.

4.2 Research Specifically Related To The Great Lakes Basin

Beginning in 1967 research programs were undertaken to study the effects of dredging and dredge disposal on the Great Lakes Basin. Complete reports of these studies are given in Appendices A through C of Corps of Engineers, 1969. The studies concentrated on eight localities:

Great Sodas Bay Harbor, New York

Buffalo Harbor, New York

Cleveland Harbor, Ohio

Rouge River, Michigan

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Table 6 – Corps of Engineers recommended research program.

Research Area	Objective	FY 73	FY 74	FY 75	FY 76	FY 77	Total
		Recommended Funding – Millions of Dollars					
1. Environmental Impacts and Aspects of Open Water Disposal		1.75	2.50	3.25	0.80	0.80	9.10
a. Evaluation of Spoil Sites	Determine the magnitude and extent of effects of spoil sites on organisms and the quality of surrounding water, and the rate, diversity, and extent such sites are recolonized by benthic flora and fauna.	0.50	0.50	0.50	0.30	0.30	
b. Fate of Dredge Spoil Materials	Develop techniques for determining the spatial and temporal distribution of dredge materials discharged into various hydrologic regimes.	0.30	0.40	0.50	--	--	
c. Effects of Dredging and Disposal on Water Quality	Determine on a regional basis the short- and long-term effects on water quality due to dredging and discharging bottom sediments containing pollutants.	0.30	0.60	0.80	0.25	0.25	
d. Effects of Dredging and Disposal on Aquatic Organisms	Determine on a regional basis the direct and indirect effects on aquatic organisms due to dredging and disposal operations.	0.30	0.60	0.60	0.25	0.25	
e. Pollution Evaluation	Develop techniques for determining the pollutional properties of various spoil types on a regional basis.	0.35	0.40	0.65	--	--	
2. Environmental Impacts and Aspects of Land Spoil Disposal		0.90	1.00	1.00	0.35	0.20	3.45
a. Environmental Impacts Studies	Identification, evaluation, and monitoring of specific short-term effects and more general long-term effects of confined and unconfined land disposal.	0.30	0.30	0.50	0.25	0.20	
b. Marsh Disposal Research	Investigation of the biological, ecological, water quality, and related problems peculiar to confined and unconfined spoil disposal on marsh or other wetlands.	0.25	0.25	0.25	0.10	--	
c. Containment Area Operation Research	Development of new or improved methods for the operation and management of confined disposal areas and associated facilities.	0.35	0.45	0.25	--	--	
3. New Spoil Disposal Concepts		--	0.30	0.85	1.00	0.96	3.10
a. Open Water Disposal Research	Investigation of environmental and economic factors involved in deepwater (oceanic) disposal, disposal in subaqueous borrow pits, and related possibilities.	--	0.30	0.45	0.25	0.25	
b. Inland Disposal Research	Evaluation of new spoil disposal possibilities such as utilizing abandoned pits and mines and investigation of systems involving long-distance transport of spoil to large inland disposal facilities.	--	--	0.15	0.30	0.25	
c. Coastal Erosion Control Studies	Investigation of methods of expanding spoil use in direct and indirect beach nourishment and development of marsh erosion and subsidence control concepts.	--	--	0.25	0.45	0.46	
4. Productive Use of Spoil		0.35	1.10	1.45	1.40	0.90	5.20
a. Artificial Habitat Creation Research	Development, testing, and evaluation of habitat creation concepts with particular attention devoted to marsh creation and spoil island habitats.	0.35	0.80	1.00	0.80	0.60	
b. Habitat Enhancement Research	Investigation of requirements for and technical feasibility of enhancing land and water habitats such as improvement of substrate conditions for sports and commercial fisheries.	--	0.20	0.30	0.30	0.30	

(Continued)

(from reference 4)

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Table 6 (continued)

Research Areas	Objective	Recommended Funding – Millions of Dollars FY 73	FY 74	FY 75	FY 76	FY 77	Total
4. Productive Uses of Spoil (Continued)							
c. Land Improvement Research	Evaluation of the use of spoil for the development or enhancement of land for agriculture and other uses.	--	--	0.15	0.15	--	
d. Products Research	Investigation of technical and economic aspects of the manufacture of marketable products.	--	0.10	--	0.15	--	
5. Spoil Area Reuse and Multiple Utilization		**0.50**	**1.10**	**1.60**	**0.55**	**0.45**	**4.20**
a. Spoil Drainage/Quality Improvement Research	Investigation of in-place spoil improvement techniques using physical, chemical, and/or biological methods.	--	0.35	0.50	0.25	0.20	
b. Wildlife Habitat Program Studies	Development and testing of wildlife- and fisheries-oriented multiple-utilization concepts for confined disposal areas.	0.20	0.30	0.40	--	--	
c. Disposal Area Reuse Research	Investigation of spoil improvement and rehandling procedures aimed at permitting the removal of spoil from containment areas for landfill or other uses elsewhere.	0.30	0.25	0.25	--	--	
d. Disposal Area Subsequent Use Research	Assessment of the technical and economic aspects of the development of disposal areas as landfill sites and the development of recreation-oriented and other public or private land use concepts.	--	0.10	0.25	0.30	0.25	
e. Disposal Area Enhancement	Evaluation of methods of improving the appearance and public acceptance of disposal areas through landscaping and related activities.	--	0.10	0.20	--	--	
6. Spoil Treatment Techniques and Equipment		**0.50**	**0.75**	**1.25**	**0.45**	**0.30**	**3.25**
a. Spoil Dewatering and Related Research	Development and testing of promising techniques for dewatering or densifying spoil slurry using mechanical and/or chemical techniques.	--	0.20	0.35	0.10	--	
b. Pollutant Constituent Removal Research	Evaluation of physical, chemical, and/or biological methods such as aeration, incineration, and coagulation for the removal and recycling of dredge spoil constituents.	0.25	0.30	0.60	0.35	0.30	
c. Turbidity Control Research	Investigation of the nature of the problem of turbidity and development of physical or chemical control methods for employment in both dredging and disposal operations.	0.25	0.25	0.30	--	--	
7. Dredging/Disposal Equipment and Techniques		--	**0.25**	**0.60**	**0.45**	**0.40**	**1.70**
a. Dredge Plant Related Studies	Investigation of dredging equipment modifications and improvements and operational improvements applicable to environmental impact reduction and spoil volume control.	--	--	0.20	0.10	--	
b. Accessory Equipment Research	Development and application of disposal operation related equipment such as silt barriers and bubble barriers for the control of turbidity and related problems.	--	0.25	0.40	0.15	0.15	
c. Spoil Transport Concept Research	Assessment of the technical and economic applicability of pipeline and vehicle transport concepts, particularly in regard to new disposal concepts.	--	--	--	0.20	0.25	
		4.00	**7.00**	**10.00**	**5.00**	**4.00**	**30.00**

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Figure 17

DREDGED MATERIAL RESEARCH PROGRAM
2nd ORDER PERT-DECISION NETWORK

(from reference 4)

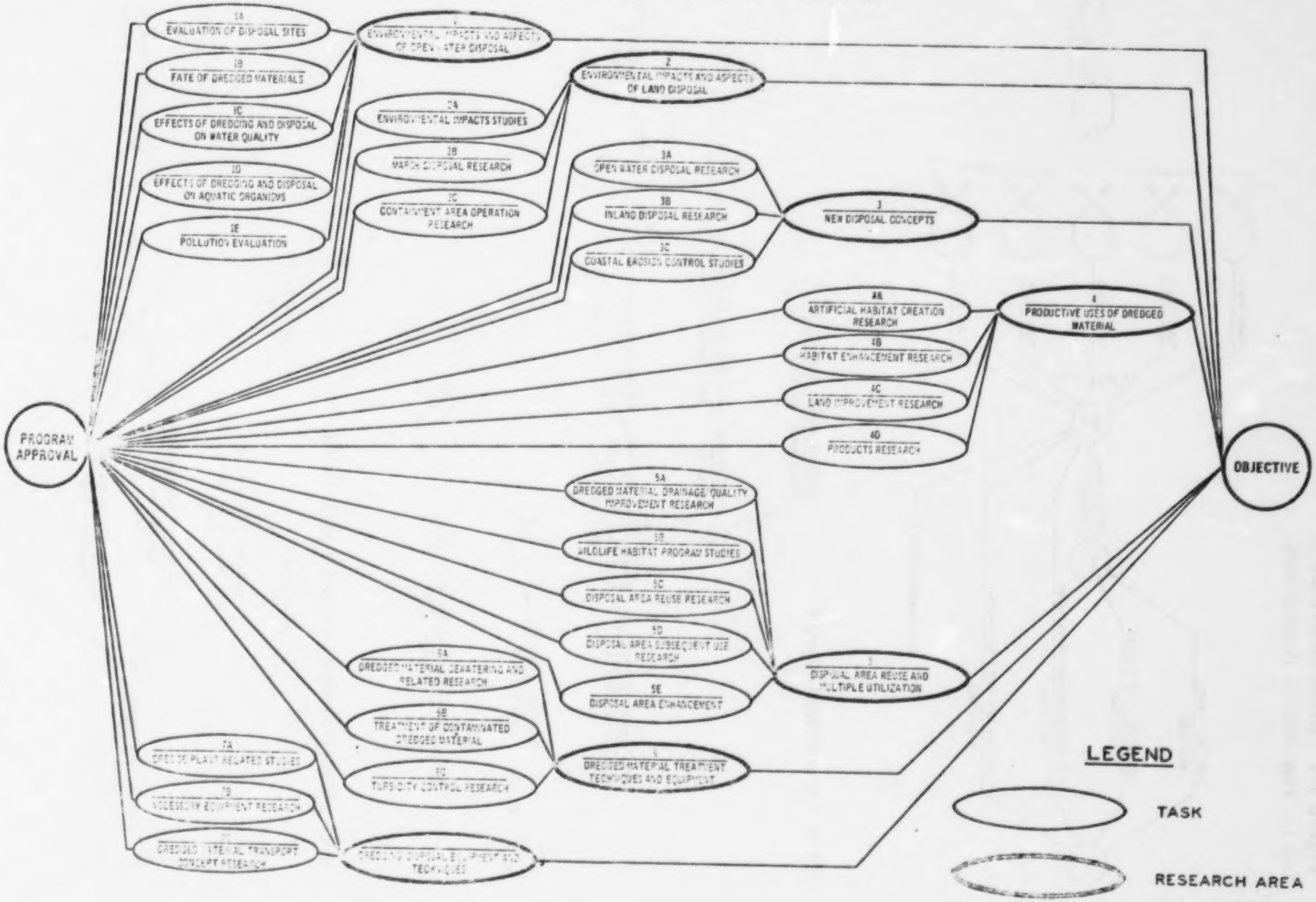
PROGRAM APPROVAL
1A EVALUATION OF DISPOSAL SITES
1B FATE OF DREDGED MATERIALS
1C EFFECTS OF DREDGING AND DISPOSAL ON WATER QUALITY
1D EFFECTS OF DREDGING AND DISPOSAL ON AQUATIC ORGANISMS
1E POLLUTION EVALUATION
1 ENVIRONMENTAL IMPACTS AND ASPECTS OF OPEN-WATER DISPOSAL
2A ENVIRONMENTAL IMPACTS STUDIES
2B MARSH DISPOSAL RESEARCH
2C CONTAINMENT AREA OPERATION RESEARCH
2 ENVIRONMENTAL IMPACTS AND ASPECTS OF LAND DISPOSAL
3A OPEN WATER DISPOSAL RESEARCH
3B INLAND DISPOSAL RESEARCH
3C COASTAL EROSION CONTROL STUDIES
3 NEW DISPOSAL CONCEPTS
4A ARTIFICIAL HABITAT CREATION RESEARCH
4B HABITAT ENHANCEMENT RESEARCH
4C LAND IMPROVEMENT RESEARCH
4D PRODUCTS RESEARCH
4 PRODUCTIVE USES OF DREDGED MATERIAL
5A DREDGED MATERIAL DRAINAGE/QUALITY IMPROVEMENT RESEARCH
5B WILDLIFE HABITAT PROGRAM STUDIES
5C DISPOSAL AREA REUSE RESEARCH
5D DISPOSAL AREA SUBSEQUENT USE RESEARCH
5E DISPOSAL AREA ENHANCEMENT
5 DISPOSAL AREA REUSE AND MULTIPLE UTILIZATION
6A DREDGED MATERIAL DEWATERING AND RELATED RESEARCH
6B TREATMENT OF CONTAMINATED DREDGED MATERIAL
6C TURBIDITY CONTROL RESEARCH
6 DREDGED MATERIAL TREATMENT TECHNIQUES AND EQUIPMENT
7A DREDGE PLANT RELATED STUDIES
7B ACCESSORY EQUIPMENT RESEARCH
DREDGED MATERIAL TRANSPORT CONCEPT RESEARCH
DREDGING DISPOSAL EQUIPMENT AND TECHNIQUES
OBJECTIVE
LEGEND
TASK
RESEARCH AREA

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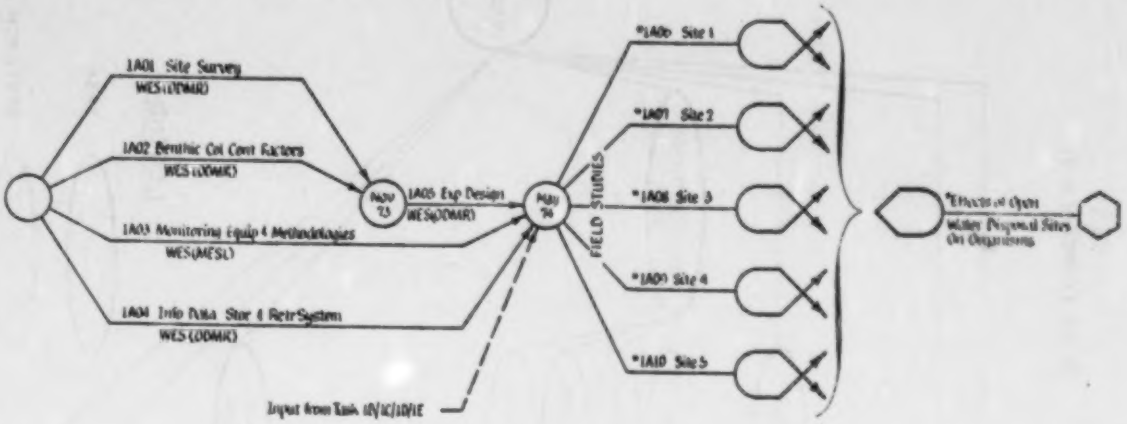
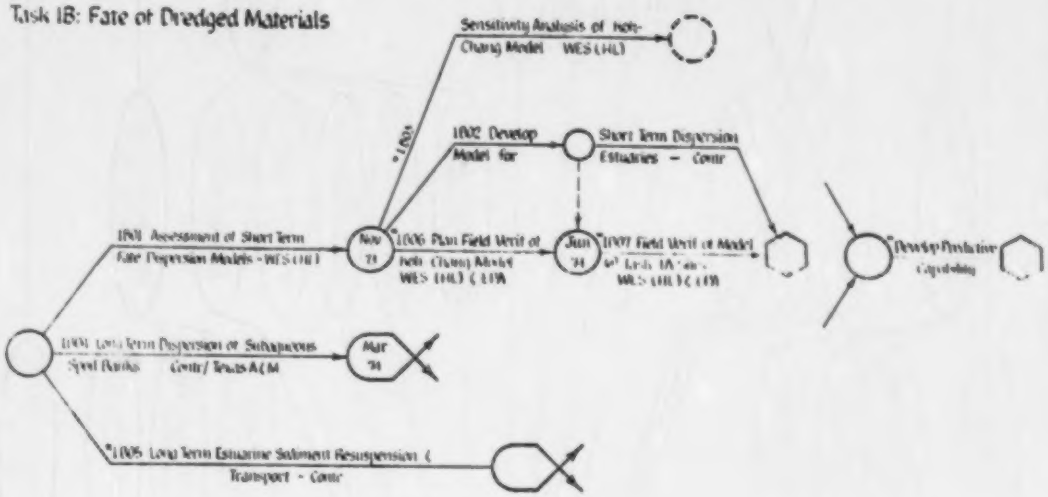
Figure 17. (from reference 4)

Task IA : Evaluation of Disposal Sites


1A01 Site Survey
WES(ODMR)
1A02 Benthic Col Cont Factors
WES(ODMR)
1A03 Monitoring Equip & Methodologies
WES(MESL)
1A04 Info Data Stor & Retr System
WES(ODMR)
Nov 73
1A05 Exp Design
WES(ODMR)
May 74
FIELD STUDIES
*1A06 Site 1
*1A07 Site 2
*1A08 Site 3
*1A09 Site 4
*1A10 Site 5
Input from Task IB/IC/ID/IE
*Effects of Open Water Disposal Sites On Organisms

Task IB: Fate of Dredged Materials


Sensitivity Analysis of Koh-Chang Model WES(HL)
*1B03
1B02 Develop Model for
Short Term Dispersion Estuaries – Contr
1B01 Assessment of Short Term Fate Dispersion Models - WES(HL)
Nov 73
*1B06 Plan Field Verif of Koh-Chang Model WES (HL) & EPA
Jun 74
*1B07 Field Verif of Model
WES (HL) & EPA
*Develop Predictive Capability
1B04 Long Term Dispersion of Subaqueous Spoil Banks Contr/Texas A&M
Mar 74
*1B05 Long Term Estuarine Sediment Resuspension & Transport - Contr

Task IC : Effects of Dredging & Disposal on Water Quality

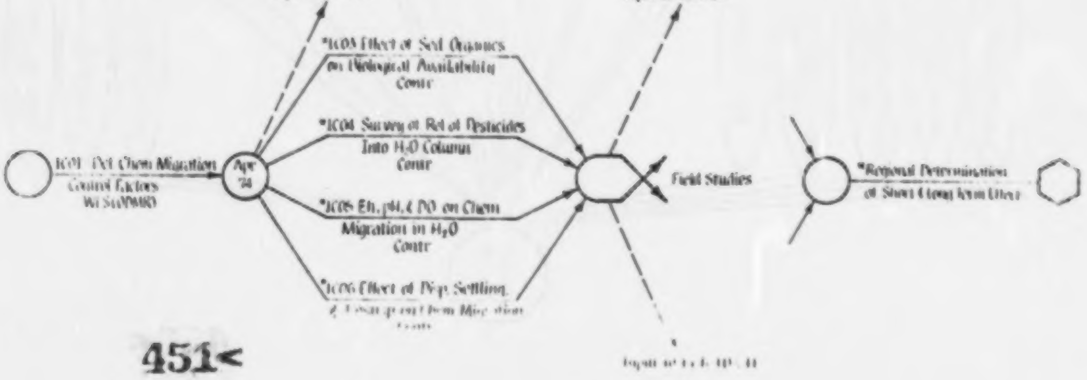

Input to Task IA
Input to Task IA
*IC03 Effect of Sed Organics on Biological Availability
Contr
*IC04 Survey of Rel of Pesticides Into H2O Column
Contr
IC01 Det Chem Migration Control Factors
WES(ODMR)
Apr 74
*IC05 Eh, pH, & DO on Chem Migration in H2O
Contr
*IC06 Effect of Disp Settling & Transport on Chem Migration
Contr
Field Studies
*Regional Determination of Short & Long Term Effect

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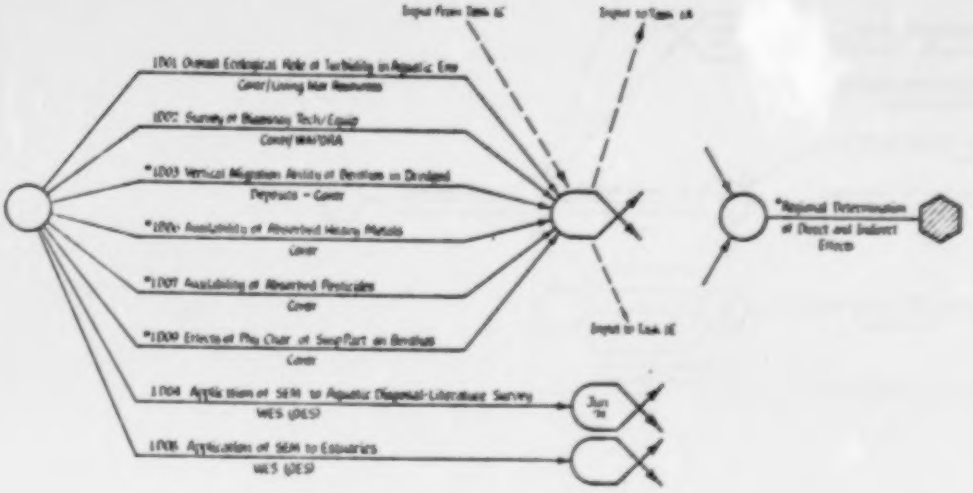
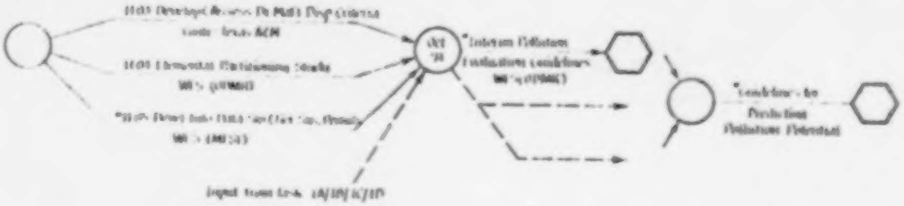
Figure 17. (from reference 4)

Task 1D: Effects of Dredging & Disposal on Aquatic Organisms


Input from Task 1C
Input to Task 1A
1D01 Overall Ecological Role of Turbidity in Aquatic Env
Cover/Living Mar Resources
1D02 Survey of Bioassay Tech/Equip
Cover/ WA/ DRA
*1D03 Vertical Migration Ability of Benthos in Dredged
Deposits – Cover
*1D06 Availability of Absorbed Heavy Metals
Cover
*1D07 Availability of Absorbed Pesticides
Cover
*1D09 Effects of Phy Char of Susp Part on Benthos
Cover
1D04 Application of SEM to Aquatic Disposal-Literature Survey
WES (DES)
Jun 74
1D08 Application of SEM to Estuaries
WES (DES)
Input to Task 1E
*Regional Determination of Direct and Indirect Effects

Task 1E: Pollution Evaluation


Oct 74
*Interim Pollution Evaluation Guidelines
*Guidelines for Predicting Pollution Potential
Input from Task 1A/1B/1C/1D

Task 2A/2B: Environmental Impact Studies

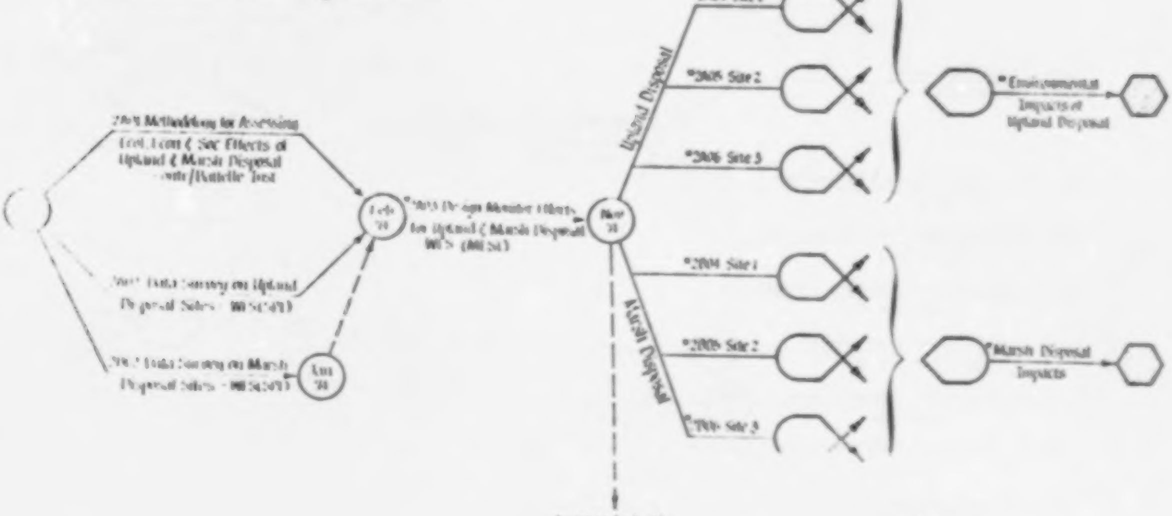


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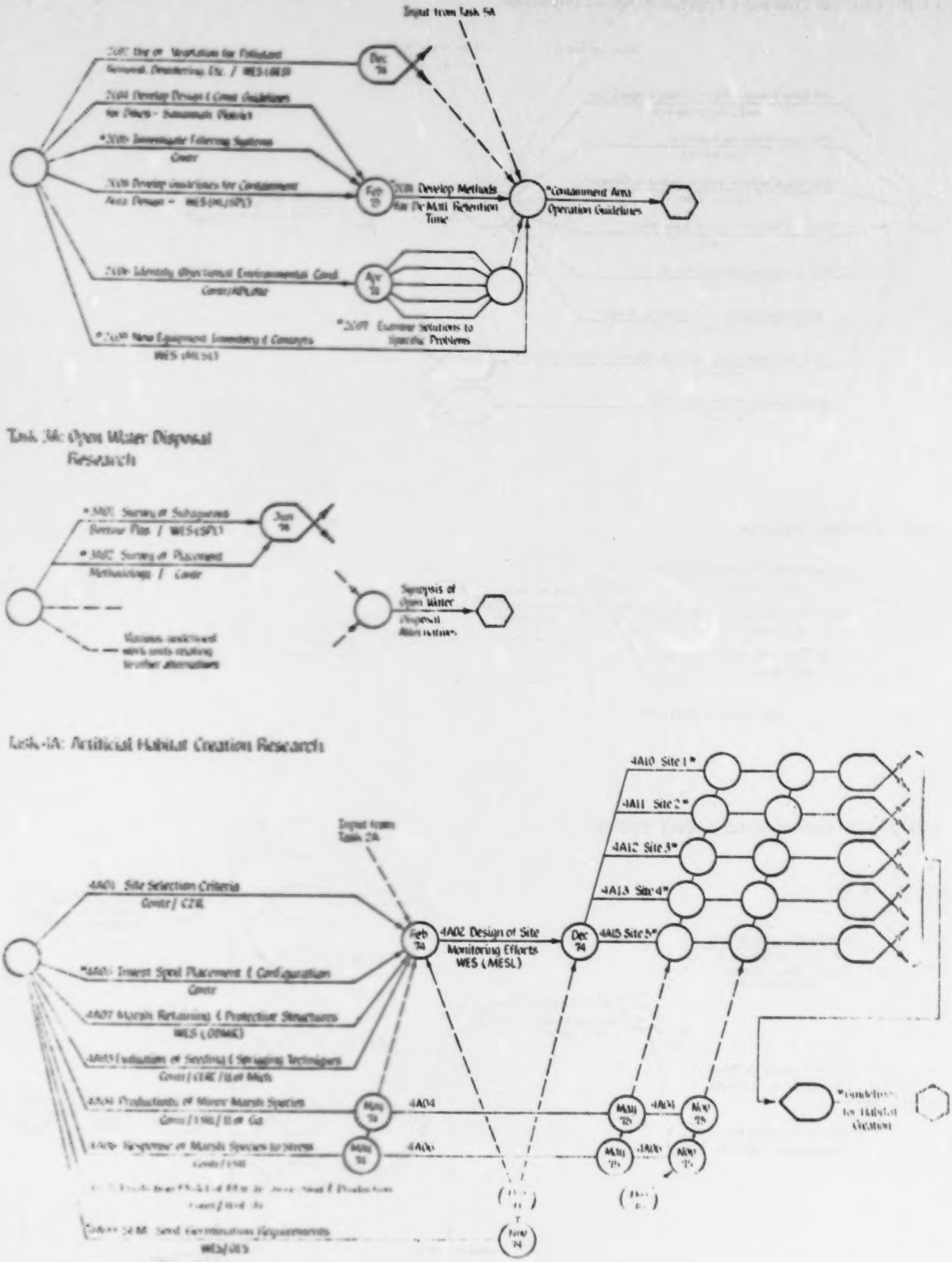
Figure 17. (from reference 4)



Task 2C: Containment Area Operation Research

Task 3A: Open Water Disposal Research

Task 4A: Artificial Habitat Creation Research

Input from Task 5A
Dec 74
Feb 75
2C08 Develop Methods for De Mill Retention Time
*Containment Area Operation Guidelines
Apr 75
*2C07 Examine Solutions to Specific Problems
Jun 74
Synopsis of Open Water Disposal Alternatives
Input from Task 2A
4A01 Site Selection Criteria
Contr / CERC
Feb 74
4A02 Design of Site Monitoring Efforts WES (MESL)
Dec 74
4A10 Site 1*
4A11 Site 2*
4A12 Site 3*
4A13 Site 4*
4A15 Site 5*
4A07 Marsh Retaining & Protective Structures
WES (ODMC)
4A04
4A06
Nov 74
*Guidelines for Habitat Creation

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Figure 17.

(from reference 4)

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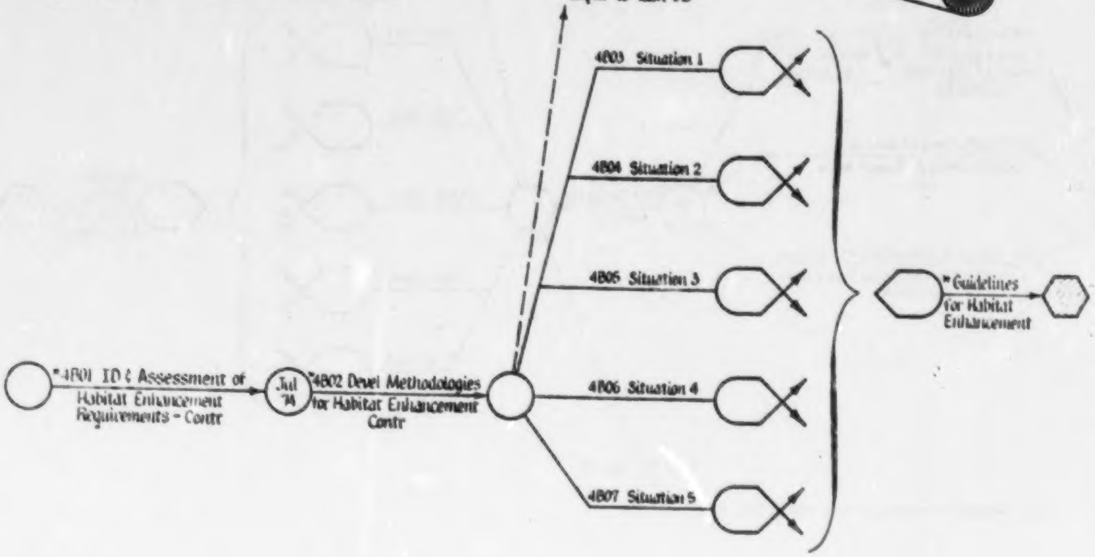
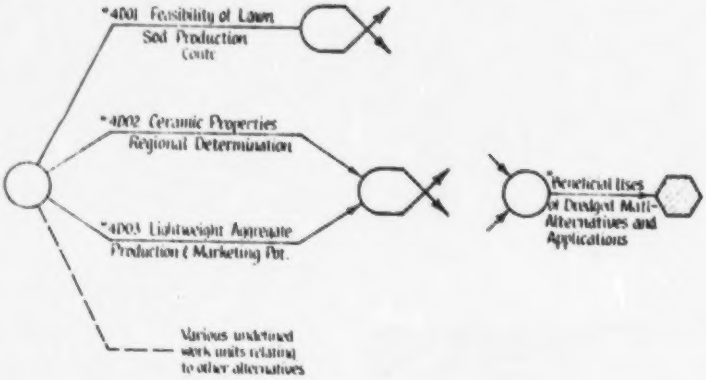
Task 4B : Habitat Enhancement Research


Input to Task 5B
4B03 Situation 1
4B04 Situation 2
4B05 Situation 3
4B06 Situation 4
4B07 Situation 5
*4B01 ID & Assessment of Habitat Enhancement Requirements - Contr
Jul 74
*4B02 Devel Methodologies for Habitat Enhancement Contr
*Guidelines for Habitat Enhancement

Task 4D : Products Research


*4D01 Feasibility of Lawn Sod Production Contr
*4D02 Ceramic Properties Regional Determination
*4D03 Lightweight Aggregate Production & Marketing Pot.
Various undefined work units relating to other alternatives
*Beneficial Uses of Dredged Matl- Alternatives and Applications

Task 5A: Dredged Material Drainage/Quality Improvement Research

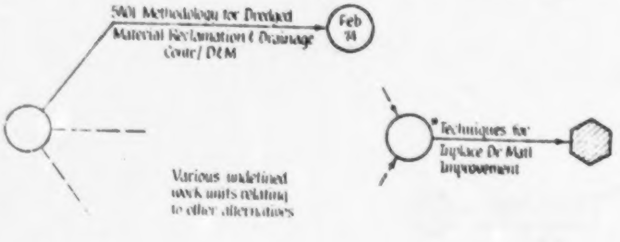
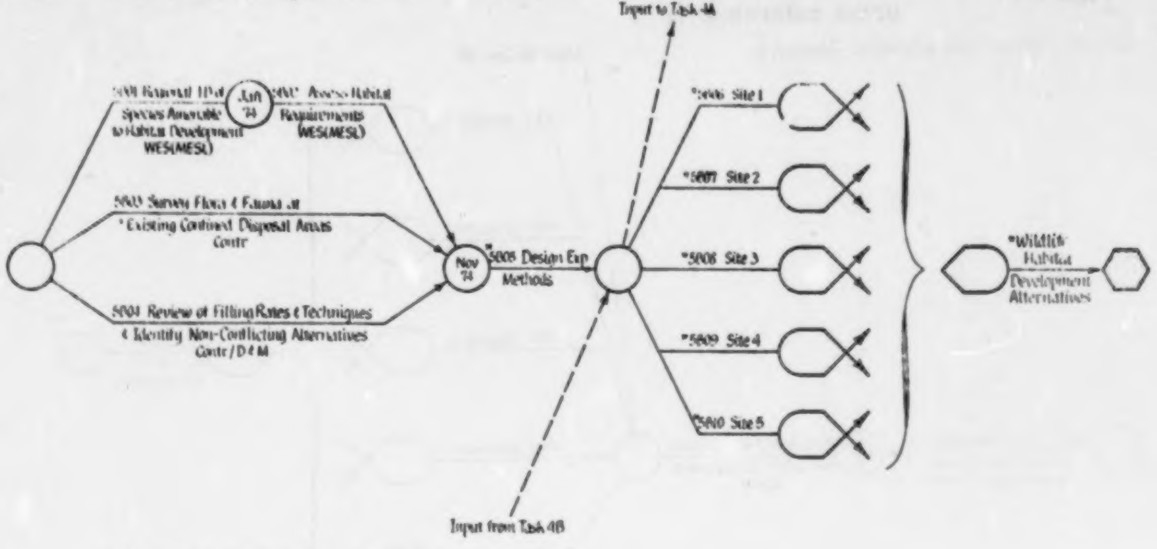

5A01 Methodology for Dredged Material Reclamation & Drainage Contr/ DEM
Feb 74
Various undefined work units relating to other alternatives
*Techniques for Inplace De Matl Improvement

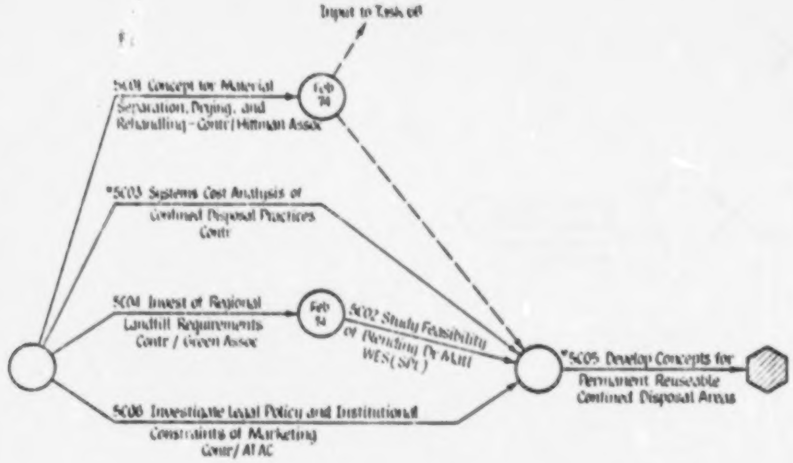
Figure 17. (from reference 4)

Task 5B: Wildlife Habitat Program Studies


Input to Task 4A
5001 Regional ID of Species Amenable to Habitat Development WES(MESL)
Jun 74
5002 Assess Habitat Requirements WES(MESL)
5003 Survey Flora & Fauna at *Existing Confined Disposal Areas Contr
5004 Review of Filling Rates & Techniques & Identify Non-Conflicting Alternatives Contr / D & M
Nov 74
*5005 Design Exp Methods
*5006 Site 1
*5007 Site 2
*5008 Site 3
*5009 Site 4
*5010 Site 5
*Wildlife Habitat Development Alternatives
Input from Task 4B

Note: Sites will correspond to sites used in Task 2A, 2B, & 4A

Task 5C: Disposal Area Reuse Research


Input to Task 6B
5C01 Concept for Material Separation, Drying, and Rehandling - Contr / Hittman Assoc
Feb 74
*5C03 Systems Cost Analysis of Confined Disposal Practices Contr
5C04 Invest of Regional Landfill Requirements Contr / Green Assoc
Feb 74
5C02 Study Feasibility of Blending Dr Matl WES(SPL)
5C06 Investigate Legal Policy and Institutional Constraints of Marketing Contr / AT AC
*5C05 Develop Concepts for Permanent Reuseable Confined Disposal Areas

Task 5D: Disposal Area Subsequent Use Research

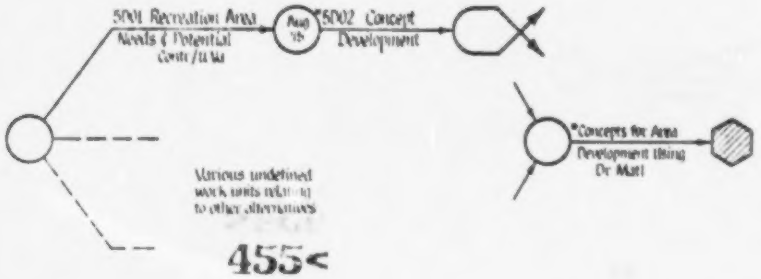

5001 Recreation Area Needs & Potential Contr / UWu
Aug 75
*5002 Concept Development
*Concepts for Area Development Using Dr Matl
Various undefined work units relating to other alternatives

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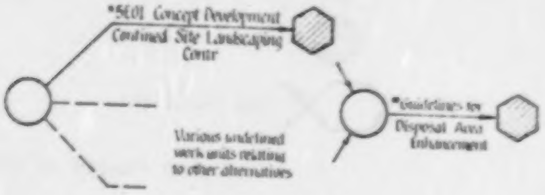
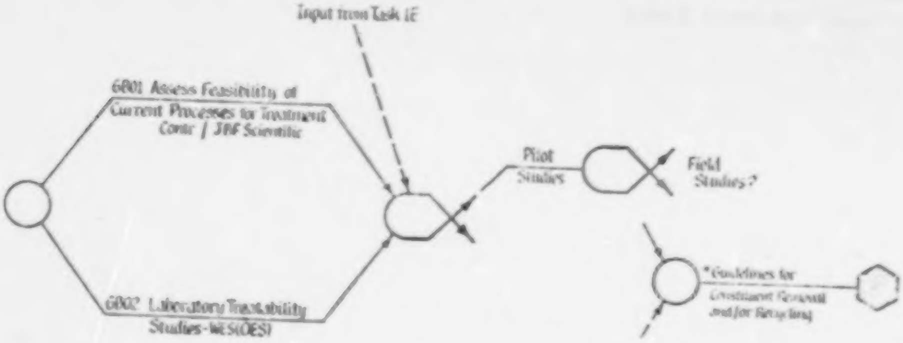
Figure 17. (from reference 4)

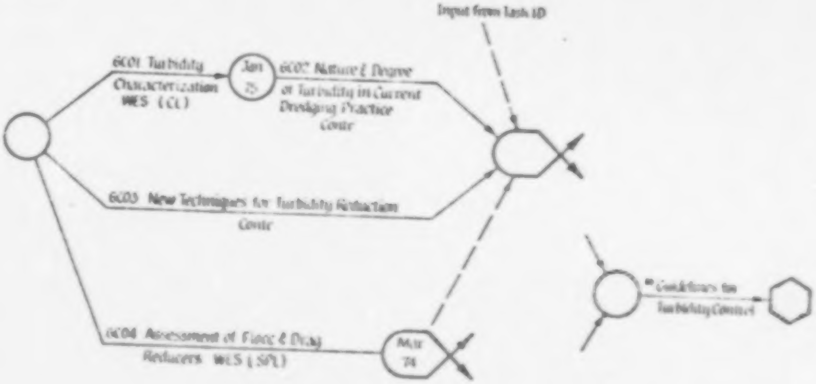
Task 5E : Disposal Area Enhancement



Task 6B : Treatment of Contaminated Dredged Material



Task 6C: Turbidity Control Research



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LEGEND

Abbreviations

ATAC	American Technical Assistance Corp.
CERC	Coastal Engineering Research Center
CZR	Coastal Zone Resources Corp.
D&M	Dames & Moore
EPA	Environmental Protection Agency
HL	Hydraulics Laboratory
I/A	Interagency Agreement
LSU	Louisiana State University
MESL	Mobility and Environmental Systems Laboratory
ODMR	Office of Dredged Material Research
OES	Office for Environmental Studies
SEM	Simulated Ecosystem Modeling
SPL	Soils and Pavements Laboratory
WES	Waterways Experiment Station

Symbols

○	Link Node
⬢	Sink Event
⬡	Decision Event
*	Work Unit Planned by not Initiated

Indiana Harbor, Indiana

Calumet River and Harbor, Illinois

Green Bay Harbor, Wisconsin

Toledo Harbor, Ohio

These harbors and rivers were selected to provide a spectrum of relevant parameters.

The studies were undertaken by the Corps of Engineers in conjunction with the FWPCA. A corps research vessel and crew undertook daily sampling in the test areas. Analyses were performed in FWPCA laboratories. Table 7 lists the types of samples taken and Table 8 lists the analyses performed.

The study resulted in the proposal of tentative standards for designation of sediments as polluted or not polluted. The standards were set recognizing the difficulties discussed in section 3.3 of this report.

Visible surface effects of dredging followed the principles discussed in section 3.5 of this report. Overflow in hopper dredges produce considerable turbidity. Washoff as clamshell dredge buckets were raised also produced turbidity.

At disposal sites, the hopper unloaded while turning, resulting in more dispersion than would have resulted if dumping had been done from a still vessel. In some dredges, the hoppers had to be washed to completely clean them. Open doors on hopper dredges and barges resulted in washoff during the return trip from the disposal site.

Studies were also performed to determine the effects on aquatic life. The criteria used were based on the degree to which the dredge material stimulated or retarded growth of such species as Pontoporeia and Cladophors.

The results of the water quality analyses were inconclusive and too few analyses were performed to allow the use of statistical methods. In general the effects of dredging could not be distinguished from background data.

While most of the research described in section 4.1 is indirectly related to Great Lakes Basin problems, some involve work which in part or in whole is undertaken within or on materials from the Great Lakes basin.

TABLE 7 . Sampling Program

wind data
wave data
near surface water samples
near bottom water samples
bottom grab samples
dredge samples
disposal area effluents

TABLE 8 . Analyses Performed

Total and soluble phosphate
Total nitrogen and ammonia, organic, and nitrate
Biochemical oxygen demand (BOD)
Chemical oxygen demand (COD)
Dissolved oxygen (DO)
Oil and grease
Chloride
Iron
pH
Alkalinity
Total Solids
Dissolved solids
Suspended solids
Volatile solids
Turbidity
Eh
Coliforms, total and fecal
Benthic organisms

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Section 5

NATURE AND AVAILABILITY OF TECHNOLOGY TO COPE WITH POLLUTION PROBLEMS

5.1 Introduction

The best control of pollution is at the source. Regulatory agencies are engaged presently in a concerted effort to require municipalities and industries to treat their wastewaters more intensively to decrease their pollutants. Control of land erosion could greatly reduce the contribution of agricultural pollution. Control at the source, whether municipal, industrial, or agricultural, will require time and funds. Estimates of how soon control measures at the source will result in the reduction of pollutants to an amount equal to the natural assimilation capacity of the receiving waters is only conjecture.

Therefore, alternate disposal methods must be considered; these include: (1) alteration in equipment and procedures used in connection with open lake disposal, (2) treatment of dredged materials to remove or stabilize pollutants to a degree that the sediments could be deposited into open lake disposal areas, and (3) disposal of dredgings in diked disposal areas. The following information on this alternative has been reported by the U. S. Army Corps of Engineers (1969).

5.2 Dredge Modifications

Spillage of dredgings from a loaded hopper often occurs during the trip to open lake disposal areas. The pitch and roll of the vessel causes a portion of the hopper contents to spill through the open overflow discharge pipe. The Philadelphia District of the Corps of Engineers designed a temporary closure structure for the Markham class hopper dredge. To prevent discharge, a gate valve would be installed in the entrance of the discharge pipe. It was estimated that the cost of the installation would be about $4,600. A similar problem exists on the Lyman class dredge. The original equipment for this class vessel included a one-foot high weir gate which was used to increase the capacity of the hoppers. During modification of the hoppers a number of years ago, the weir gate was removed. It could be reinstalled at costs similar to those discussed above for the Markham class.

Consideration was given to modifying the Markham to reduce surface effects in the disposal area by discharging the dredgings at least 45 feet below the water surface. Philadelphia District designed a temporary "jury-rig" structure to test the feasibility of the plan. A 24-inch diameter piping system could be installed in lieu of the existing starboard shore pumpout connection. A 65-foot section of

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piping could be lowered with a cargo boom after the vessel had come to a complete stop in the open lake disposal area. Spoil could be pumped from the hoppers while the vessel was stationary. The estimated cost of installing the temporary structure was $28,000. Additional operating costs for using this method would be $0.06 per cubic yard.

Disposal of dredgings from hopper dredges in open lake areas normally is accomplished while the vessel is in motion. To reduce surface effects, consideration was given to stopping the dredge before discharging the dredgings. Tests were conducted on the dredge *Lyman* during maintenance dredging operations at Rochester and Buffalo in 1968. Aerial photographs and water samples were taken to determine the effects of stationary disposal compared with disposal while the dredge was underway. Stationary disposal reduces the extent of surface effects; but the dredge is required to remain stationary for a period of time or move very slowly as it leaves the area. Further, stationary disposal does not eliminate the need for washout, and this would become the major source of surface effects. Accordingly, the washout would have to be delayed until the dredge returned to the dredging area. The additional costs for increased dredge cycle time would be about: (1) $0.11 per cubic yard for *Lyman* class dredges; and (2) $0.03 per cubic yard for the *Markham*.

The normal dredging procedure with hopper dredges is to continue loading for a short time after the hoppers are filled initially. As indicated previously, this procedure increases the volume of dredged sediments that can be contained in the dredge, but it also causes some of the dredgings to be discharged back into the waters behind the dredge. It was estimated that the increase in the cost of dredging without overflow would average about $0.05 per cubic yard, but it could be as much as $0.12 per cubic yard for projects where the disposal site is a long distance from the dredging area.

While dredging Saginaw Bay, the pumping speed of the *Markham* was reduced after the hoppers were filled initially. The solids content of the overflow mixture was reduced from 18 to 12 percent by weight with no appreciable change in the cost of dredging. Similar tests were performed at Buffalo with the dredge *Lyman*, but the overflow solids content remained essentially the same as in the normal overflow. Additional tests would be required to determine the effects associated with the reduced pumping speed.

Recent modifications to dipper and clamshell dredging practices include the requirement that (1) scow pocket doors be fitted tightly to prevent leakage; (2) material spilled on the decks of scows during loading operations be washed off in the dredging area; and (3) free water in the scow pockets be spilled in the dredging area if it approaches the top of the scow pocket. To aid in the measurement of quantities dredged and to prevent spillage while moving to the disposal area, scows were leveled or trimmed before leaving the dredge. The above practices are expected to minimize surface effects from scows.

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5.3 Treatment of Dredgings

Space requirements for complete treatment equipment preclude its onboard use or its assignment to auxiliary accompanying vessels. Among the possibilities of partial treatment methods requiring a limited amount of space, the following were considered for hopper dredges: (1) aeration; (2) flocculation; and (3) chlorination. Hopper dredges normally dispose of dredgings in the open lake, but pumping into diked areas appears to be becoming a more frequent and common practice.

5.4 Diked Disposal Areas

Treatment of supernatant from disposal areas prior to discharge back into waterways, has been considered by the Corps. They engaged the Dow Chemical Corporation to make a full scale field test at the Maumee River diked disposal area using the same chemicals as for the earlier tests on board the dredge Markham. The 30-acre (12138 square meters) Riverside spoil area was used for the field test. A two-acre (809 square meters) corner was diked off to form a clarification pond. Supernatant from the main area was discharged into the clarification pond through a 250-foot (76 meters) long corrugated metal trough in which the chemicals were added. Before running the field test, many laboratory tests were run with different coagulants and aids and with a wide range of suspended solids. It was found that the flocculation was most effective with Purifloc C-31 when suspended solids were at a concentration of about 8,000 mg/l and very good at concentrations up to 20,000 mg/l. Above this level, the effectiveness decreased rapidly. Below the 8,000 mg/l level, effectiveness decreased also, but the addition of ferric chloride improved the flocculation. Ferric chloride alone was effective also, but produced a weak, light floc which settled slowly. At low concentrations of suspended solids, a combination of ferric chloride and Purifloc C-31 proved to be best.

The concentration of suspended solids in the water discharged into the coagulation pond was only 60 mg/l during the 48-hour field test at the disposal area. Chemicals used were 33 mg/l of ferric chloride and 7.5 mg/l of Purifloc C-31. Suspended solids were reduced to as little as 10 mg/l; phosphates decreased from 0.16 to 0.10 mg/l; coliform count dropped from 14,700 to 9,000 per 100 ml; and chemical oxygen demand and dissolved oxygen increased slightly. The cost of chemicals used was $0.01 per cubic yard of dredging. Dow Chemical Corporation believes that the concentration of suspended solids was too low for an optimum test. Actually, there should be little need for coagulation with so low a level of suspended solids. With higher concentrations, it is probable that the ferric chloride could be eliminated and the same results could be obtained using the same amount of polymer.

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Section 6

NEED FOR NEW RESEARCH, DEMONSTRATION OR MONITORING PROGRAMS

In reviewing ongoing and planned research, it appears that a well conceived and supported program of research is available through the Waterways Experiment Station. However, it does not appear that adequate steps are being taken to insure that problems relevant to the specific needs of the Great Lakes are being met by the research program. It is, therefore, recommended that the Great Lakes Basin Commission take steps to insure that projects be undertaken that involve data taken within the Great Lakes or on Great Lakes dredgings and dredge spoil. A particularly worthwhile endeavor would be to make prospective investigators on Corps of Engineers projects aware of the wealth of background data available through the GLBC on the nature of the environment within the Great Lakes basin. This would serve to encourage prospective investigators to select study sites within the Great Lakes Basin.

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Section 7

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Land Use/Water Quality Relationships in the U. S. Great Lakes Basin
Task A: To assess problems, management of programs and research...
Category A16 - Deep Well Disposal

DEEP WELL INDUSTRIAL-WASTE DISPOSAL

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Section 1

SUMMARY

1.1 Introduction

For scores of years huge quantities of liquid waste have been injected underground and presently more than a billion gallons a day are pumped into subsurface units. The vast majority of these wastes has consisted of oil-field brines and, although there have been several reported cases of fresh ground-water contamination caused by their injection, the techniques are quite reliable and well established. Within the past 30 years there has been an increasing number of other types of wastes injected and the techniques used are similar to the older more established oil-field brine disposal methods. The return of an oil-field brine to the original producing zone, however, may differ considerably in hydrodynamics and geochemistry from deep-well disposal of certain other industrial wastes.

Within the past 10 years deep-well disposal techniques have become more sophisticasted and regulations more demanding. The number of disposal wells has also increased significantly in the past few years - from about 10 in 1953 to more than 275 in 1972 (Warner and Orcutt, 1973). Their increase is largely due to the recognition by industry that they represent an attractive and, in most cases, less expensive means of disposing of highly toxic or noxious liquid-waste products. In addition, these wastes are believed to be stored in a confined reservoir system that is far removed from topographic and climatic influences and in which vertical migration is insignificant. In many situations these assumptions have proved to be invalid.

In the Great Lakes Basin, deep-well disposal of liquid industrial waste has not received wide support from state regulatory agencies, nor is such support likely in the near future. None the less there are reportedly more than 100 disposal wells in the basin, but, of these several have been abandoned and a few have not been used as of February, 1974 (Warner and Orcutt, 1973; Michigan Department of Natural Resources, pers. comm.). Included in this tabulation are 56 wells in Michigan and one each in Ohio and Pennsylvania that dispose of brine or processed brine in operations that are not associated with oil-field operations.

Neither Wisconsin nor Minnesota have any disposal wells. It is the general policy of the Wisconsin Department of Natural Resources to prohibit the injection of any material into the subsurface, including natural gas for storage. That part of Minnesota that lies in the basin consists largely of strata too impermeable to permit injection.

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Three disposal wells have been drilled in the Great Lakes drainage basin in New York State but none is presently in operation. The Bethlehem Steel Company well at Lackawanna is to be used for disposal of waste pickle liquors and, although a permit has been issued, injection had not started as late as January, 1974. Hooker Chemical Corporation at Niagara Falls installed a well to dispose of hydrochloric acid, but a buyer for the excess acid was found and the well was never used. The FMC Corporation at Middleport installed a well for the disposal of pesticides but a permit to discharge was not issued. These wells were completed in the Theresa-Potsdam Formations of Cambrian age, which form the potential disposal zone.

Three disposal wells were completed in Erie County, Pennsylvania, in 1965 (2) and 1968 by the Hammermill Paper Company. These wells, which range in depth from 490 to 1555 meters (1,610 to 5,100 feet), tap the Bass Islands Dolomite and the deeper Gatesburg Sandstone. The Gatesburg section was tested but not used. These wells were used to dispose of spent sulfite pulping liquors, which were injected at rates ranging from 470 to 3,030 liters per minute (189 to 800 gallons per minute). All three wells are now plugged and abandoned. Reportedly in 1968 one of the connectors broke off one of the wells and for several days the waste backflowed into Lake Erie until the well was shut in (International Joint Commission, 1972). In Pennsylvania there are no known reservoirs of truly good disposal quality (Rudd, 1972) and consequently there will very likely not be many future deep-well disposal projects, in spite of a great need.

Deep-well disposal techniques were initiated in Ohio in 1967 and since that time 9 permits have been issued (Clifford, 1972). Five of these wells lie in the Lake Erie basin. In 1971 Calhio Division of Stauffer Chemical Corporation drilled a disposal well at their plant in Lake County. The Kerbel and Mt. Simon units were tested. The maximum well depth was 1700 meters. The well is to be used for the injection of a sodium chloride brine and organic materials. In Cuyahoga County the International Salt Company injects a natural brine into the Oriskany Sandstone at a depth of 437 meters. Apparently the brine leaks downward from the Oriskany into a mine in the Salina Formation of Silurian age where it is pumped to the surface and into the injection well. Vistron Division of Sohio at Lima in Allen County utilizes three disposal wells, 975 meters deep in order to inject sulfate solutions with HCN and acrilonitrile wastes. These wells were drilled in 1968, 1969, and 1971. In 1971 the Ohio Liquid Disposal Corporation drilled a well to 915 meters in Sandusky County. The request for a permit to inject liquid effluent from many different sources was denied.

The State of Michigan has not only the greatest number of disposal wells but also the greatest number of problems. There are 88 known wells that inject fluids into either salt cavities or Paleozoic strata. Most of these are brine disposal wells (Sec. 3.1) and at least 15 of these have been abandoned or shut down, while several others are not yet in use. Most of the injection wells were drilled between 1949 and 1973. The major injection zones include the Detroit River, Dundee, Sylvania, Traverse, Filer, Salina, and Mt. Simon formations. The wells are spread throughout the lower part of the lower peninsula. Specific sites include Midland, Pontiac, Bay City, Ludington, Holland, Kalamazoo, Detroit, Mio, Montague, St. Louis, Alma, Wyandotte and Manistee (data from files of Michigan Department of Natural Resources).

Apparently the wastes that are injected include a wide variety of substances. The industries that own injection wells include a laudromat, Dow Chemical, Heinz, Parke-Davis, Chemetron, Upjohn, Ford Motor, Hoskins Mfg. Co., Dupont, Michigan Chemical Co., Total-Leonard Refining Co., Penwalt Chemical Co., Morton Salt, Morton Chemical, Hardy Salt, and Martin-Marietta.

Several ground-water and surface-water contamination problems resulting from deep-well disposal have occurred in Michigan throughout the past few years. In the lower half of Michigan bedrock formations contain many abandoned and unplugged oil, gas, and brine wells (Deutsch, 1963). Fluids can discharge through these open holes to the surface or flow into shallow ground-water aquifers. North of Marine City a brine well was drilled into the Detroit River Group about 1900. In 1966 this abandoned well began to flow salty water. In Port Huron in 1967 several old unplotted oil and gas wells also began to flow because of chemical wastes that were being injected into the Detroit River Group in Sarnia, Ontario (International Joint Commission, 1972). In addition, near Sarnia in 1966 phenolic compounds flowed up an unknown well beneath a building and this also was due to pressure increases brought on by subsurface injection of waste materials. In Ludington, Michigan, a waste brine well began to leak and contaminated a shallow fresh-water aquifer. Reportedly, there is a great abundance of shallow aquifer, and some surface water, contamination throughout the lower part of Michigan, some of which has been caused by corroded casing in either brine or disposal wells.

Michigan's problems, relative to deep-well disposal, are related to two major phenomena. The most significant and also the most difficult to alleviate is due to the presence of many unplotted and abandoned wells and test holes that have been drilled into formations containing salty water. Some of these wells were drilled in the latter part of the 19th century in search of brines for lumber mills. Since 1927, regulations have required that permits be issued for drilling wells and that the wells be plugged upon abandonment. The second major cause of contamination is related to the highly corrosive nature of some of the wastes that are injected.

In the vicinity of Gary, Indiana, nine disposal wells, tapping the Mt. Simon, are used to inject hydrochloric and sulfuric acid waste pickle liquors. In this region the Mt. Simon is about 550 meters thick and the injection wells have an average depth of about 1220 meters. Reportedly waste pickle liquors may be injected into these wells by gravity at rates as high was 640,000 liters per day (Bayazeed and Donaldson, 1973).

Although a few deep disposal wells occur in Illinois, none lie within the drainage basin of Lake Michigan. A disposal well test, however, was carried out in DuPage County by means of a well drilled into the Precambrian basement (Bergstrom, 1968a, b, c). Near the bottom of the overlying Mt. Simon Sandstone, the intended injection zone, formational fluids contained as much as 95,000 mg/l of dissolved solids. The concept of a deep disposal well in DuPage County had to be abandoned, however, since the State has largely forbidden disposal in the northern fourth of the state in order to protect deeply buried but only slightly salty reservoirs that may serve as a future drinking-water source. In addition, the state Sanitary Water Board ruled that fracturing of the basal part of the Mt. Simon Sandstone in DuPage County would not be permitted. Another problem presented by this site was the extent to which water of poor quality might migrate upward as a result of injection of waste into the lower part of the sandstone and the pumping of potable water from the upper part.

More recently thought again has turned to the DuPage County site (Schicht, 1973). The development and desalting of moderately mineralized water contained in the Mt. Simon in northeastern Illinois is being considered as a means to supplement the impending water shortage in the Chicago region. It is visualized that slightly saline water could be pumped from the upper part of the Mt. Simon, desalted, and the desalted plant waste brine injected to the lower part fo the formation. An injection well field has been designed that would theoretically eliminate contamination of the feed water and keep the injection pressures within acceptable limits. The individual wells were designed to inject 3,785,000 liters a day. The Illinois State Water Survey is continuing to evaluate this situation.

1.2 Summary of Findings and Conclusions

Both ground-water and surface-water pollution problems associated with deep well disposal have been identified in Michigan and in Pennsylvania (International Joint Commission, 1972). Existing legislation or policy statements appear to be adequate throughout the basin to control potential pollution problems, as they are now understood. Legislation in Michigan, the major user of this waste management technique and the major problem area is adequate to cope with development and operation of future deep well injection systems. On the other hand, the great abundance of abandoned wells and test holes whose locations are largely unknown and which man penetrate the formations used for waste storage prohibit adequate controls in spite of the legislation.

Problems do not appear to be serious at the present time, but could become so later in the century if the number of wells and volumes of wastes increases at rates similar to those in the recent past. Data indicate that deep-well disposal in the Great Lakes Basin has not adversely affected the quality of the Great Lakes water. All examples of contamination are local and the contaminated water that may reach the streams is small in volume and rapidly diluted. Although a few regional studies bearing on the problems of deep-well waste management are in progress, there are many questions concerning the hydrodynamics and the geochemistry of the injection horizons that could be investigated. Studies such as these could produce a better understanding of waste movement in the confining layers and the interaction including the possible natural degradation processes, of the injected wastes in the formations or with the formation waters.

1.2.1 Consideration Should Be Given to the Initiation of The Following Programs

1.2.1.1 Registry of Injection Wells

A registry of subsurface injection sites with accompanying geological, geophysical, engineering and chemical data, both of the waste and formational fluid on each well site should be formulated. Maps indicating the theoretical migration of the wastes, based upon the volumes and rates of injection of the wastes, should be produced. Although the wastes are not thought to travel great distances from the injection site in the theoretical ideal case (Bayazeed and Donaldson, 1973) the expected positions in the subsurface should be mapped.

Changes in the potentiometric surfaces in the vicinity of the well should also be calculated and recorded. These records should be supplemented by observations from monitoring wells where possible. The availability of data such as these would be of use to deep-well disposal contractors and designers, administrators, and researchers. They would probably be of greatest value in those areas where there are numerous disposal wells or where expected subsurface resources might be sought.

1.2.1.2 Monitoring Wells

Demonstration systems of monitoring wells for one or more parts of the basin, where waste injection is extensive as near Gary, Indiana, or southern Michigan, would aid in answering many of the potential problems outlined in Section 6, regarding the storage of wastes. It may also aid in the development of predictive models to be used to determine the capacity of subsurface units to store wastes.

1.2.1.3 Determination of Subsurface Space Available for Wastes

Maps and stratigraphic sections showing actual or potential waste storage formations should be compiled for the basin. Some areas have already been so mapped. The availability of these data would provide some indication of the rate at which we are using underground space for storage and might result in a more rational use of this resource. The delineation of the areas might contain several categories of suitability. In addition, categories of waste, based on toxicities and possibilities for degradation, might also be developed. These tools when used in a matrix would aid in the evaluation of subsurface space for storage of wastes.

Section 2

SUPPORTING MATERIAL

2.1 Introduction

Deep-well waste disposal techniques have been practiced for decades, primarily for the disposal of brines produced in oil-field operations. Since about 1950 deep well disposal of industrial wastes has become an increasingly popular solution for elimination of toxic or noxious unwanted liquids. By June 1973 there were 278 known industrial wastewater-injection wells in 24 states in the Nation (Warner and Orcutt, 1973). Of these, 51 (not including brines or processed brines) lie within the Great Lakes Basin drainage system, but several have been permanently or temporarily abandoned or have not been placed in operation. It is reasonable to expect that the use of the deep-well disposal technique may increase within the next few years as the industrial complex seeks alternative methods of waste-water disposal.

The early deep-well disposal techniques were, with slight modification, those developed in the oil industry (Piper, 1969). Apparently only limited consideration was given to well design, operation, and maintenance or to the chemical nature of a corrosive waste (which occasionally resulted in leaky well systems), or to the chemical reaction between waste waters and formation materials or waters. In some oil-field operations, the brines were used to repressurize oil-producing zones, but in deep-well disposal operations, the additional pressure provides opportunities for contamination of adjacent formations due to several mechanisms, including flow through poorly plugged or uncased holes. As a result, new techniques of design and operation of wells, new criteria for determining formation suitability, and new regulations were developed in some areas. The high cost of detailed investigations, which now are commonly required before permits will be issued, may reduce the rate of proliferation of this technique of waste management. Deep-well disposal techniques do remove wastes from the biosphere and it appears to be a reasonable method under proper conditions. In addition to the potential pollution problem, questions are now being raised as to alternative uses of underground space that might be filled with waste waters in the future.

2.2 Scope of Study

Data sources used in this discussion included those abstracts, reports, memoranda and published papers that applied primarily but not exclusively to deep-well disposal in the Great Lakes Basin. The time frame considered was from 1950 to 1975, although most of the information has been published within the last 10 years. Furthermore most of the significant research has appeared within the past three or four years. Research in progress in the Great Lakes Basin states is minimal.

2.3 Study Procedures

2.3.1 The study was accomplished largely by means of a search of available literature in order to determine the state of deep-well disposal and management of liquid wastes that are largely industrial in origin. Information obtained by telephone contacts and correspondence, largely from state agencies in the Great Lakes Basin, represent inputs from both management and research positions. Synthesis of these data and materials followed in the summary of the problem and current research, as well as in development projections of future uses of deep-well disposal techniques and waste management.

2.3.2 Telephone conversations with several members of the Ohio Department of Natural Resources, Ohio Environmental Protection Agency, and the Michigan Department of Natural Resources were the only oral communications with investigators and managers during the course of this study. Additional information, however, was derived by correspondence and accompanied reports submitted in response to information requested.

2.3.3 The major sources of literature reviewed included professional journals, symposia proceedings, and state and federal reports. Of particular value were the Water Supply Papers published by the U. S. Geological Survey, annotated bibliographies published by the Environmental Protection Agency and Selected Water Resources Abstracts, which are published by the Office of Water Resources Research. Additionally, several reports from the governments of Canada and Ontario were consulted in order to determine possible unique problems or additional avenues of research. A search of The Ohio State University library system using the Mechanized Information Center produced a computer printout of 36 references on the subject that have appeared within the last 12 years.

2.3.4 For purposes of this study, it has been assumed that the published literature, unpublished reports, and first-hand knowledge obtained from local, state, and federal officials is indicative of the state-of-the-art of deep well disposal and associated problems as they actually exist. Many occurrences of both surface-water and ground-water contamination related to deep-well disposal operations, are of local extent and difficult to detect. Knowledge of them is sparse unless an event has been brought to the attention of a regulatory agency. In the majority of cases, this is not often done. This does not necessarily mean that the unknown conditions reflect insignificant situations. Furthermore, industrial concerns are unlikely to freely provide information relative to contamination of water supplies in view of the likelihood of civil or criminal actions that might be initiated to their detriment.

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Section 3

REVIEW OF FINDINGS OF PREVIOUS STUDIES

3.1 General Description of Land Use Category

Deep-well disposal is the injection of liquid wastes, such as brine and industrial or commercial materials into the subsurface. The disposal of oil-field brines by this technique has been practiced for over half a century and has had the secondary benefit of repressurizing the producing formations in many cases. Although much of the technology used in subsurface injection of wastes developed in the oil industry, this aspect of waste management is not directly considered here. Most of the wastes injected are high-strength organics, caustics,acids, or other toxic materials, but, particularly in Michigan, there are numerous wells that dispose of processed brines. These brine wells, while not strictly of the oil-field type, are in many cases operated in a similar way and may be thought of as repressurinzing the formation from which the brines were originally removed. Thus the potential problems associated with industrial brine wells are not as severe as those associated with industrial-waste wells.

Another aspect of nomenclature in need of clarification is the use of the term "deep-well" for all operations that inject waste water into the subsurface or underground. In some cases the wells are, or were, less than 461 meters, which in most areas would be considered as a shallow well. In one instance in the basin, a well 91 meters deep was used for disposal. Although the report has been produced under the title of "Deep-Well Industrial Waste Disposal", it should be kept in mind that the wastes include some industrial brines and that some of the wells are shallow.

The use of subsurface reservoirs as a receptacle for industrial wastes has increased greatly within the past 20 years as documented elsewhere in this report. Economic factors have been partly responsible since some industries have found it less expensive to switch to subsurface disposal than to continue surface treatment of wastes. Other industries found that they could no longer dump partially treated or untreated wastes into surface streams under new regulations designed to improve water quality. Such industries also sought to solve their waste management problems by subsurface injection.

The space into which the liquid wastes are injected is obtained partly by displacement of water in the formation, partly by compression of the fluids, and partly by expansion of the formation matrix. Ideally the receiving formation is bounded both above and below by formations of low vertical permeability. Even with such precautions upward flow can occur if high injection pressures are used and hydrofracturing has occurred.

3.1.1 Waste Disposal or Waste Storage

The use of the term "disposal" in the process of subsurface injection of wastes is sometimes considered to be erroneous

(Cleary & Warner, 1969). Generally wastes are merely stored in subsurface space. Wastes will seldom be contained forever in one place but usually they will be confined and move only under restricted conditions that may be predicted or monitored (Drescher, 1965).

3.1.2 Design and Operation of Wells

Determination of the suitability of disposal zones depends on many geologic and hydrologic properties of the subsurface and other factors such as the risk of seismic events, unplugged or poorly plugged wells, possible useable resources in the subsurface and the characteristics of the waste to be injected. Criteria for determining the suitability of these zones are being developed by state and other agencies. A list of the application information considered desirable by ORSANCO (1973) is given in Table 1; more detailed data requirements are suggested by the U.S. Environmental Protection Agency (Hall and Ballentine, 1973). Some states have been mapped on the basis of suitability for subsurface waste injection and in these states administrators may use informal guidelines in treating applications on the basis of the location of the proposed well in the state (Bergstrom, 1968b).

One reason for the need for detailed information on a proposed site is the possible reaction of wastes with the formation or formation waters and subsequent reduction in the permeability of the receiving formation. Additional problems concerning composition of the wastes are given in Table 2 and useful information for evaluation of wastes for injection underground are in Table 3. At least one well in Ohio and one in New York have not received permits for injection because of the unknown or hazardous nature of the wastes.

One example of the design of an injection well and associated pretreatment system is given in Figure 1. Pretreatment is needed to avoid problems listed in Table 2 and to make wastes more compatible with the receiving formation and thus extend the useful life of the well. Some wells use a non-corrosive fluid under pressure in the annular space between the injection tubing and the well casing. Changes in the monitored pressure in this space, indicating a leak has occurred by corrosion or failure of the injection tube or casing, could automatically shut down the well. Other designs show injection of non-corrosive waters into the formation through the annular space as the wast is injected through the central string of tubing (Bayazeed and Donaldson, 1973). Accidents due to failure of the injection tubing by corrosion have resulted in use of fibercast tubing in some places, in order to reduce this hazard.

3.2 Length of Time Activities in Practice

Operation of subsurface industrial waste-disposal systems

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TABLE 1. OUTLINE OF SCOPE AND CONTENT OF A FEASIBILITY REPORT TO ACCOMPANY AN APPLICATION TO DRILL AND TEST A WELL (AFTER ORSANCO, 1973)

I. WELL LOCATION

A. General map and description of well location showing cultural and geographic features and boundaries of property owned or leased by the applicant.

B. Detailed plat showing proposed injection well site and locations of all types of existing wells within two miles of injection well site. Plat should also include all wells penetrating the proposed injection horizon and its confining beds, within five miles.

C. Records of wells shown in detailed plat, including ownership, available subsurface information, and well-plugging data.

II. GEOLOGY AND GEOHYDROLOGY

A. Structural geologic features in the immediate and general vicinity of the well location. Provide a surface geologic map.

B. Geologic and engineering description of subsurface rock units.

  1. General types and characteristics including a geologic column.

  2. Potential injection horizons and confining beds with reference to: lithology; thickness; areal distribution; porosity; permeability; reservoir pressure and temperature; chemical characteristics of reservoir fluids; formation breakdown or fracture pressure; hydrodynamics.

C. Geohydrology of fresh-water aquifers at the site and in the vicinity with respect to depth; thickness; general character; and usage.

D. Mineral resources and their occurrence at the well site and in the immediate area such as: oil and gas; coal; brines; and any other deposits of significance.

E. Seismicity - Location and intensity of earthquakes recorded in area.

TABLE 1. (Cont'd)

III. RESERVOIR RESPONSE AND WASTEWATER MIGRATION

- A. Estimated pressure build-up with time (at the well bore and at 100, 1,000, and 10,000 feet from the well bore). (feet x 0.305 = meters)
- B. Predicted rate and direction of wastewater movement.

IV. PROPOSED WELL DESIGN, CONSTRUCTION AND TESTING PROCEDURES

- A. Drilling, coring, and testing program
- B. Casing and tubing - size, grade, type, weight, setting depth
- C. Cement - type including additives and amount
- D. Other subsurface equipment
- E. Well-head equipment

V. PROPOSED SURFACE EQUIPMENT

- A. Holding tanks, flow lines, filters and pumps
- B. Flow, pressure, and other monitoring devices
- C. Other equipment or control devices

VI. CHARACTERISTICS OF UNTREATED WASTES

- A. Industrial process from which waste is derived
- B. Physical and chemical description of waste - including variations
- C. Volume - including variability in rate of production
- D. Compatibility with subsurface fluids

VII. ALTERNATIVE DISPOSAL METHODS

- A. Description of alternative disposal strategies
- B. Comparison of alternatives with respect to both economic and environmental considerations, and justification for decision to use underground injection.

VIII. PROPOSED PRE-INJECTION WASTE TREATMENT

- A. Settling
- B. Filtration

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TABLE 1. (Cont'd)

C. Chemical Treatment

D. Concentration or Dilution

E. Other

IX. PROPOSED OPERATING PROGRAM

A. Injection schedule including average and maximum rates, and estimated yearly total for each year through projected well life.

B. Injection pressures including average and maximum

C. Monitoring techniques

X. PROPOSED CONTINGENCY PLAN IN EVENT OF UNANTICIPATED WELL FAILURES

TABLE 2. OPERATIONAL PROBLEMS RELATED TO WASTE CHARACTER (AFTER ORSANCO, 1973)

Problem of Concern	Means of Evaluating	Means of Controlling Undesirable Effects
REACTION		
Wastes and formation minerals	Laboratory tests and observation of system	Preinjection waste treatment
Wastes and formation water	Laboratory tests	Preinjection waste treatment or a buffer zone
Autoreaction of waste at formation temperature and pressure	Laboratory tests	Preinjection waste treatment
Wastes and system components	Laboratory tests and observation of system	Preinjection waste treatment, addition of corrosion inhibitors to waste, and use of corrosion-resistant materials
MICROORGANISMS		
	Laboratory tests and observation of system	Preinjection waste treatment and addition of biocides
SUSPENDED SOLIDS		
	Laboratory tests and observation of system	Preinjection waste treatment or formation treatment
ENTRAINED OR DISSOLVED GASES		
	Laboratory tests and observation of system	Chemical or mechanical degasification

TABLE 3. FACTORS TO BE CONSIDERED IN EVALUATING THE SUITABILITY OF UNTREATED WASTES FOR DEEP-WELL DISPOSAL (AFTER ORSANCO, 1973)

A. Volume

B. Physical Characteristics

  1. Specific Gravity
  2. Temperature
  3. Suspended solids content
  4. Gas content

C. Chemical Characteristics

  1. Chemical constitutents
  2. pH
  3. Chemical stability
  4. Reactivity
     a. With system components
     b. With formation waters
     c. With formation
  5. Toxicity

D. Biological Characteristics

began in the 1930's in the United States (Warner and Orcutt, 1973). In the Great Lakes region the first wells in Indiana were drilled by American Cyanamid at Michigan City to a depth of 90 meters (295 feet) in 1951. Earlier, an injection well was constructed in Michigan in 1949.

3.3 Types and Nature of Pollutants.

A classification of industrial liquid wastes has been proposed by Piper (1969) that is similar to a classification for radioactive wastes devised by the American Institute of Chemical Engineers. A brief summary of this classification, based on the relative concentrations and toxicities, is given in Table 4.

In the Great Lakes Basin injected wastes include pickle liquors (acids) from the steel industry, waste brines and sulfates from the salt and chemical industries, sulfide pulping liquors from the paper industry, organic materials such as acrilonitrile and pharmaceutical wastes, and laundromat wastes. A variety of other substances including pesticides have been proposed for injection. In some instances the actual type of waste, its composition and concentrations is unknown or proprietary.

These wastes are foreign to the receiving formations and contaminate such formations; however, the formations act as storage reservoirs for wastes and should prevent contamination of other resources or areas. The injected wastes do, in most cases, preclude the use of the underground space for other resource extraction or storage.

3.4 Problem Assessment and Quantification

Assessment of problems associated with deep-well injection of industrial wastes is primarily on a case-by-case basis except where regional suitabilities have been delineated (ORSANCO, 1973, Bergstrom, 1968b). In most areas regulations on sites, waste injection (types, concentrations, quantities, pressures), and design and operation of wells reduce the chance of problems developing according to today's knowledge of what is happening

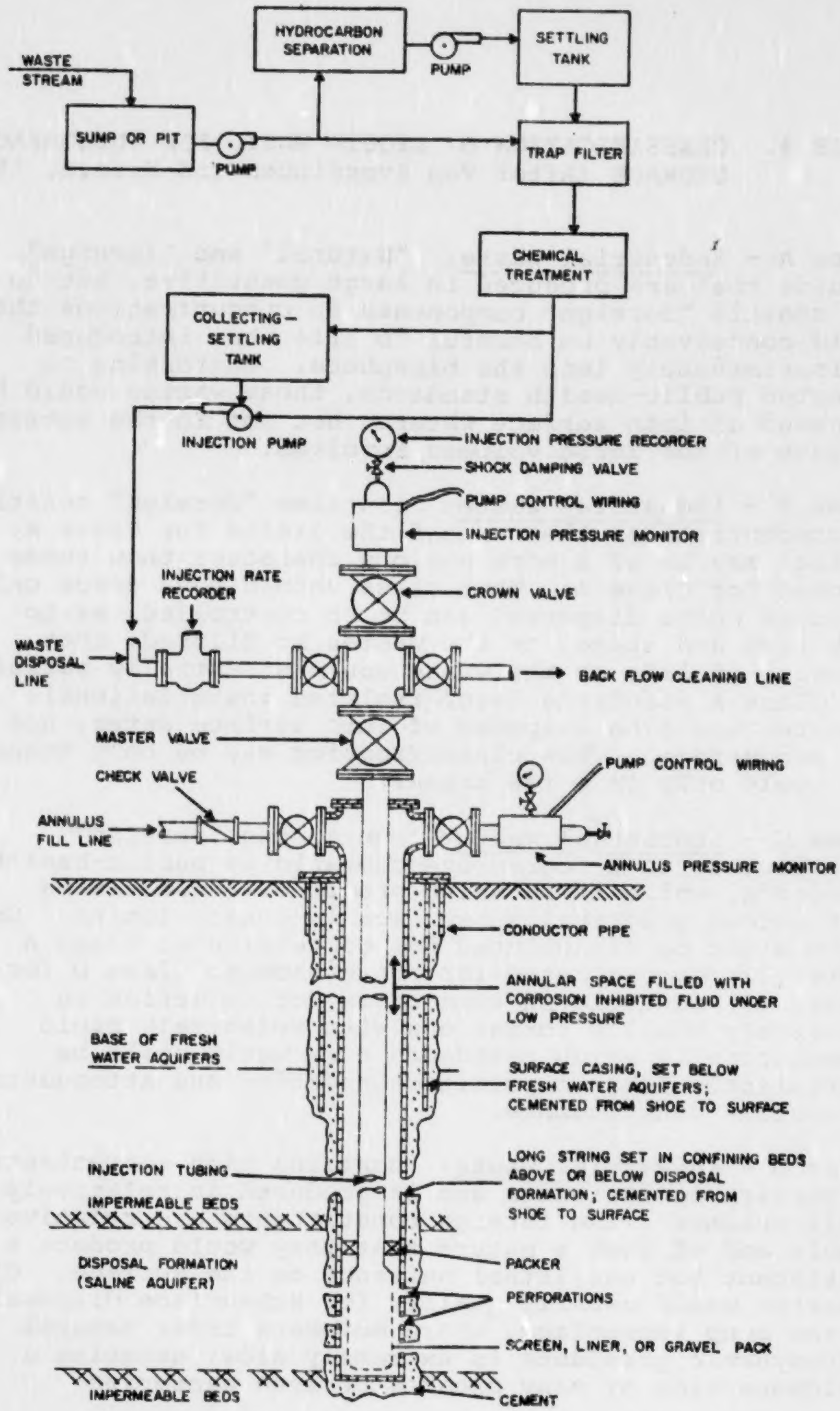

Figure 1. *Schematic diagram of pre-injection treatment system and injection well.* (After van Everdingen and Freeze, 1971)

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TABLE 4. CLASSIFICATION OF LIQUID WASTE FOR SUBSURFACE STORAGE (After Van Everdingen and Freeze, 1971)

Class A - industrial waste: "Natural" and "foreign" liquids that are produced in large quantities, but do not contain "foreign" components in concentrations that would conceivably be harmful to life when introduced indiscriminately into the biosphere. Conforming to accepted public-health standards, these wastes could be disposed of into surface waters, but not in the subsurface because of the large volumes involved.

Class B - industrial waste: contains "foreign" constituents in concentrations that exceed the limits for Class A, or that may be of a more noxious character than those allowed for Class A. This class should have force only in areas where dispersal can be so controlled, as to both time and space, or the wastes so diluted, that exposure of life to the waste would essentially satisfy the Class A standards (e.g. isolated installations). Class B wastes would be disposed of into surface water, not in the subsurface. This classification may be only transient and apply only in a few areas.

Class C - industrial waste: containing "foreign" constituents to a degree unacceptable by public-health standards, while it is being produced in quantities that exceed practical subsurface injection limits. Such waste might be (1) diluted for conversion to Class A waste; (2) concentrated for conversion to Class D (or E) waste; (3) suitable in some cases for injection in relatively shallow formations with relatively rapid circulation in which residence time would still be sufficiently long to permit degradation and attenuation of noxious constituents.

Class D - industrial waste: contains high concentrations of foreign constituents and is produced in relatively small volumes. The foreign constituents are relatively stable and of such a nature that they would produce a persistent but non-lethal nuisance on the surface. Class D wastes would usually qualify for subsurface disposal in the deep subsurface, where movement under natural hydrodynamic gradients is extremely slow, assuring a residence time of many decades or even centuries.

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TABLE 4. (Cont'd)

Class E - industrial waste: liquid wastes of such persistent noxiousness and concentration that they must be excluded from the biosphere essentially forever, necessitating unequivocal and detailed knowledge of their disposition at all times (e.g. chemical/biological warfare agents). Absolute immobility in the subsurface cannot be assured; detailed monitoring of subsurface movement is virtually impossible. Class E industrial wastes are therefore not qualified for subsurface disposal.

in the subsurface. Unknown problems may actually be developing but hydrodynamic or geochemical parameters are unavailable to predict the long-term effects. To more adequately determine what conditions exist in the subsurface, observation wells would be needed, but apparently none exist in the basin because of the additional expense. According to van Everdingen and Freeze (1971) "...research into subsurface disposal of waste is a wide-open field."

The development and use of guidelines for a feasibility report (Table 1) as suggested by ORSANCO (1973) should reduce the chance of problems developing in a particular well. Delineation of suitable areas, a cautious approach to issuing permits, or a policy of not permitting any subsurface injections as apparently is the case in both Wisconsin and Minnesota, should minimize the chance of future problems. Increased use of this waste management technique in some areas of the basin would necessitate better understanding of the mobility and reaction possibilities of the wastes.

3.4.1 Contamination of Resources

The problems associated with subsurface management of industrial wastes include not only the possibilities of contamination of fresh water aquifers and surface waters by blowouts or by underground discharge to streams, but also the possible contamination of coal, oil, gas, and even brackish water that may later become a resource. In the latter case, Illinois is considering all aquifers with less than 5,000 mg/l of dissolved solids as a potential fresh-water source and thus unsuitable for waste injection (Bergstrom, 1968b).

Another type of resource is the brines themselves which have been used in the chemical industry for decades in Michigan, Ohio, New York, and Pennsylvania and may be important elsewhere.

3.4.2 Loss of Storage Space

Another aspect of waste injection is the loss of space for storage of natural gas or fresh water within the salt water zones (Kimbler et al., 1973). Assessment of the future need for these spaces for storage of such resources or confinement of the most toxic wastes is difficult. We may be eliminating important resources or creating some long-range pollution problems in order to "dispose" of wastes in a manner that is now economical. Concern over this problem has been expressed in several reports and in some areas has resulted in regulations that require proof that injection is the best, and not just the least expensive, way to handle the waste.

3.4.3 Seismic Events

Earthquakes may be associated with use of underground space as was demonstrated in Denver (Evans, 1966).

Most of these problems, although important, are secondary considerations to the possible contamination of the Great Lakes by discharge of injected wastes or displaced brines into the streams or lakes in the basin.

3.5 Mobility of Pollutants in Ground-Water and Surface-Water Systems

Many of the liquid wastes that are discharged into injection wells in the Great Lakes Basin receive some surface treatment, although actual data appear to be lacking (Warner and Orcutt, 1973). Pre-injection waste treatment largely consists of filtration in order to decrease the potential of plugging the injection zone. In some instances there is no treatment.

Little information based on empirical data is available that describes the mobility of various contaminants in the deep subsurface. An understanding of their mobility in the underground environment is complicated because of the various chemical reactions that occur due to differences in composition in the natural formation fluid and the mineralogy of the injection strata.

Experience with the reaction of various contaminants in shallow aquifers and surface water supplies, however, sheds some light on this problem and suggests that some substances are highly mobile (Deutsch, 1963). Generally those wastes that contain sulfate and chloride, which include many of the wastes presently being injected, are highly mobile due to the general lack of degradation phenomena such as sorption and ion exchange. The only effect on their concentration is related to dilution and dispersion.

Although many of the wastes substances have the potential for high mobility, they probably do not move any great distance in adjacent underground reservoirs. Their mobility becomes a problem and, in some cases a significant problem, due to injection well failure or migration of the fluid through unplugged or abandoned holes. The high mobility of brines and phenolic compounds are well exemplified by contamination examples in Michigan and Ontario.

3.6 Natural Renovation of Wastes

Natural renovation mechanisms have been demonstrated for waste pickle liquor, particularly hydrochloric acid that is used in the steel industry (Bayazeed and Donaldson, 1973). Laboratory tests using rock samples of the Mt. Simon Sandstone from Fulton County, Indiana, indicate a reduction in the iron concentration due to absorption as the waste solution migrates laterally from the injection well. The tests also showed a reduction in the hydrochloric acid concentration resulting in solute-depleted zones at the front of the advancing fluid. The lateral migration of injected fluid, consequently, creates its own buffer zones because of depletion of the waste near the well. Artificial buffer zones developed by first injecting fresh water, or a non-toxic tracer fluid that could easily be detected by monitor wells, might be used to determine the approach of an advancing waste solution.

Apparently depletion of all types of pickle liquor wastes near this well would not be the same as it was for hydrochloric acid pickle liquor. Tests on sulfuric acid waste-pickle liquor did not show the same improvement in quality (Bayazeed & Donaldson, 1973) illustrating the importance of knowing more about the possible geochemical reactions of wastes in each case.

Neutralization of acid solutions that are injected into carbonate formations or into sandstone with carbonate cement also occurs. Dissolution along fractures and in cavities would be expected and would increase permeability of the formation resulting in improved injection. Increase in the hardness of the water would also be expected. Natural renovation of wastes by neutralization of acids has been demonstrated in Florida (Goolsby, 1971).

Decrease in the toxicity of low-level radioactive waste will also occur in storage and could be considered as a natural renovation process.

Investigation of possible reactions, under different temperature and pressure conditions, between injected waste waters and the formation or the formation fluids should be undertaken to determine the possibilities for immobilization of waste products and reduction in toxicities. Much research on both the hydrodynamic and geochemical aspects of natural renovation of waste waters could be undertaken. Because of variability in the geologic and hydrologic environments, and the many types of wastes being disposed, the applicability of results from such research may not be widespread.

3.7 Probable Changes in Land Use

The general lack of good waste disposal reservoirs in Pennsylvania will serve as a damper to their future use (Rudd, 1972). Although various Illinois state regulatory agencies do not prohibit the use of deep injection wells they are not encouraged, in fact the general trend is to prohibit their use in the northeastern part of the state largely because of the availability of fresh water or only slightly saline waters throughout a great depth. As the water-supply situation becomes more critical in the Chicago metropolitan complex, a limited number of injection wells may be constructed for the disposal of desalting plant brines. It is strongly suspected, however, that their construction and operation will be closely followed by state agencies.

The five existing deep-disposal wells in northern Ohio apparently have been operating with but few problems. A recent modification of Ohio statutes, however, prohibits the injection of any waste materials into the ground. If this statute remains in force, there will be no increase in the number of injection wells in the State. Even though the law might be changed in time, well disposal regulations are so strict and the construction so costly that the number of new wells drilled will be minimal.

Presently there are no injection wells in Minnesota and Wisconsin and in view of the general subsurface conditions and the reluctance of the state agencies to encourage their use, it is unlikely that the situation will change in these states. There is a great need for waste disposal sites in New York State and deep-well disposal may provide part of the solution. The New York Geological Survey in cooperation with the U. S. Geological Survey is studying the hydrology of the Theresa-Pottsdam Formation, which serves as the major injection zone in the Great Lakes drainage basin area. Conclusions relative to deep-well disposal in these units have not as yet been drawn. If, however, the hydrologic conditions are favorable, it is strongly suspected that more wells will be constructed.

In view of the industrial complex spread along Lake Michigan in Indiana, the abundance of liquid wastes, and the apparent success with existing injection wells, it is to be expected that the use of deep-well disposal techniques will be continued. The future increase in the number of injection wells will depend on the success of the existing fields and the rules and regulations established by the Indiana legislature. Deep-well disposal of liquid wastes has been practiced in Michigan for 25 years and it is strongly suspected that this method will not only continue in use but that the number of injection wells will increase significantly. In view of the new regulations established by Act No. 315 of the Public Acts of 1969 of the State of Michigan, there is little question that the disposal systems will be constructed and operated much more carefully than in the past. The major problem in Michigan is related to the discharge of effluent from plugged and abandoned test wells and exploratory holes due to the increased pressure resulting from deep-well injection.

3.8 Projected Seriousness of Future Pollution Problems

The seriousness of future deep-well disposal problems will be closely related to the administration of legal controls by various state agencies and the construction, operation, and maintenance of injection equipment. Even with the most sophisticated systems equipment can fail at any time causing waste to discharge into shallower fresh water aquifers, the ground, or into water courses. Problems such as these are manageable and should not lead to significant occurrences of contamination if proper management techniques are enforced. If state laws and regulations are inadequate, undoubtedly problems will continue to occur. Liquid waste injection in some geological situations can result in seismic activity as evidenced in Denver, Colorado, but problems of this nature are not well understood. Injection at high pressures can cause hydrofracing, which will increase not only the permeability of the injection zone but may fracture confining layers. This may result in upward migration of waste materials.

Available data indicate that most future deep-well injection problems have the greatest potential for occurrence in the State of Michigan (Deutsch, 1963). This is largely due to the abundance of unknown and abandoned test wells and holes that penetrate the major injection zone. Similar problems could occur in parts of northern Ohio where also there is an abundance of unknown old oil and gas wells and test holes. It is unlikely that the problem will become very serious in Ohio, however, because of the legal controls already established. Additional contamination problems could develop in Michigan associated with escape of waste solutions through collapsed strata above salt caverns.

3.9 Review of Regulations

Ohio was the first state in the Great Lakes Basin to establish specific regulations concerning deep-well waste disposal. The regulations were formulated in 1967. Michigan soon followed with the Mineral Well Act, Act. No. 315 of the Public Acts of 1969. The effective date of this Act was July 15, 1972, and formal implementation reportedly began in 1973. Elsewhere no specific deep-well disposal laws exist, but several policy statements have been issued. Injection well policy was established in New York in 1969 and in Illinois in 1970. Related legislation was formed in Indiana in 1969.

Where there are no specific statutes, deep-well disposal permits are regulated most frequently through water pollution control, health, environmental protection or oil and gas agencies or a combination of these departments.

If followed to the final letter, existing laws, regulations, and policy appear to be adequate from a legalistic point-of-view. Although supporting data are unavailable, it appears that the level of funding available to the regulatory agencies is inadequate. Furthermore, available personnel are too few in number and, in some cases, too inexperienced with the specifics of deep-well disposal to adequately carry out many of their duties.

A potential interstate conflict in deep-well disposal philosophy may develop between the States of Indiana and Illinois. The general policy in Illinois is to prohibit disposal in the northeastern part of the State, whereas in adjacent parts of Indiana several injection systems are in operation. International problems have resulted from subsurface waste disposal activities between Michigan and Ontario and, although the regulations have been improved in the past decade the nature of the subsurface and the unknown wells in both areas may result in future problems.

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Section 4

SUMMARY OF RELEVANT ONGOING OR PROPOSED RESEARCH, DEMONSTRATION, OR MONITORING PROGRAMS THAT MAY HELP ANSWER BASIC QUESTIONS

4.1 Relevant Regional Investigations

Basic questions, geochemical and hydrodynamic in nature, were addressed in several papers presented at the second symposium on underground waste management and artificial recharge (Braunstein, 1973). The applicability of these results and numerous case histories also reported concerning many wells in operation in this country and abroad, will only help our understanding of the process. An increased general-knowledge base plus continued surveillance over operating wells and careful consideration of requests for new wells will serve to further reduce the possibility of contamination of water supplies.

Research that probably would be of greatest immediate benefit in protecting the basin would be that of investigating the hydrodynamic, geochemical, and geologic factors in the areas of actual or proposed injection. These data could be used to improve and support administrative decisions regarding requests for new wells.

Only a few ongoing or recently completed projects were found to be directly related to answering questions on subsurface injection in the basin. Other applicable research may be underway, but was not reported by the state agencies contacted.

4.1.1 Illinois

Bond, D. C., 1972, Hydrodynamics in deep aquifers of the Illinois basin: Illinois Geological Survey Circ. 470.

Schicht, R. J., 1973, Deep-well injection of desalting-plant waste brine, in Braunstein, J., (ed.) Underground waste management and artificial recharge: AAPG, v. 1, p. 652 - 663.

Heidari, M. and others, computer simulations of disposal wells, Illinois Geological Survey; in progress.

4.1.2 Indiana

Bayazeed, A. F. and Donaldson, E. C., 1973, Subsurface disposal of Pickle Liquor: U. S. Bureau of Mines, R.I. 7804, 31 p.

4.1.3 Ohio

Clifford, M. J., 1973, Hydrodynamics of the Mount Simon sandstone, Ohio, and adjoining areas, in Braunstein, J., (ed.) Underground waste management and artificial recharge: AAPG, v. 1, p. 349-356.

4.1.4 Pennsylvania

Rudd, Neilson, 1972, Subsurface liquid waste disposal and its feasibility in Pennsylvania: Pennsylvania Geological Survey, Environmental Geology Report 3.

4.1.5 Ohio River Basin

ORSANCO, Registry on injection-well systems in the eight states of the basin, U.S.G.S. supporting grant; in progress.

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Section 5

NATURE AND AVAILABILITY OF TECHNOLOGY TO COPE WITH POLLUTION PROBLEMS

Pollution problems that result from deep-well disposal operations are of two types based on the rate at which contamination occurs. Accidents such as well blowouts or poorly plugged wells may cause very rapid pollution of surface waters as was the case in Pennsylvania. Slower accidental contamination of ground waters may occur if wastes leak through fractures in the casing or through poor seals between the confining formations and the casing. Contamination of an aquifer could occur over many years without detection as wastes migrate laterally and vertically under a modified ground-water flow system.

5.1 Nature of Technology

Pollution of surface or subsurface water from a faulty well can be stopped by ceasing operation. A standby well, storage lagoons, or a waste-treatment facility should be available to handle wastes in the case of accidents and during maintenance.

The quality of the polluted surface waters may be improved in several hours or days, mainly by dilution. However, subsurface reservoirs may remain polluted for centuries depending on the type of waste and ground-water flow rates. Thus pollution by equipment failure or by migration from the containment zone could prove hazardous to subsurface resources.

In rare instances it might be possible to flush these resources with fresh water to eliminate the contamination, but this would be costly even if possible.

The use of alarm systems to shut down the wells during equipment failure and the installation of monitoring wells may be the best technical solutions to potential pollution problems.

Section 6

NEED FOR NEW RESEARCH, DEMONSTRATION OR MONITORING PROGRAMS

6.1 Gaps in Knowledge by 1976

6.1.1

As indicated in Section 4, regional research on hydrogeologic and geochemical factors of waste disposal would be beneficial to the Great Lakes Basin. Techniques of registering operations as developed by ORSANCO may prove useful for a similar program in the Great Lakes Basin. These data could be used for additional research and also for administrative purposes.

6.1.2

Much general research on subsurface injection may be applicable to the Great Lakes Basin. Many possible avenues for research have been described by ORSANCO (1973), and van Everdingen and Freeze (1971). Advances in some of these research areas will take place by 1976, however, it is impossible to determine with information now available in which areas the results most applicable to the basin will occur. Regional studies in the basin are not expected to be significant in number unless there is some future mechanism for obtaining adequate funds and associated scientific and management interest.

6.2 New Studies Required

6.2.1

New studies required to define problem situations and to improve the safety of subsurface injection as outlined by van Everingen and Freeze (1971) are shown in Table 5.

In some areas, available knowledge suggests that the case-by-case basis, combined with strict permit and enforcement regulations, will be adequate to minimize the pollution potential. Thus funds may be of more benefit in defining and solving problems in other parts of the basin.

6.2.2

The geohydrologic system from one state to the next as within each state is unique and therefore, demonstration projects incorporating the more sophisticated techniques are urgently needed.

6.2.3

Additional studies and programs concerning a registry of injection wells and determination of subsurface space available for waste storage are given in Section 1.2.1.

TABLE 5.

SUBJECTS IN NEED OF RESEARCH
(from van Everdingen and Freeze, 1971)

PHYSICS

A. Injection-well hydraulics

1. Validity of pumping-test equations for injection tests.
2. Pressure-distance-time relationships under non-ideal geologic conditions.
3. Injection-well hydraulics in fractured media.
4. Validity of ground-water equations in low-permeability confining layers.
5. Optimization of observation-and-monitor-well design.

B. Stress Mechanics.

1. Prediction of maximum safe injection pressure.
2. Physical nature of hydraulic fracturing and its relation to natural stress fields.
3. Effect of hydraulic fracturing on confining beds.
4. Possibility of positive use of hydraulic fracturing in subsurface disposal of waste.

C. Hydrodynamics.

1. Proper location of waste-disposal wells in relation to local and regional groundwater-flow systems.
2. Methods for prediction of both natural and induced hydrodynamic gradients.
3. Relative importance of geochemical osmosis as a fluid-driving force.

D. Dispersion

1. Application of hydrodynamic-dispersion theory to injection of waste into the subsurface.

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2. Nature of interface between waste and formation fluids; dispersion, fingering; gravitational segregation resulting from density differences.

3. Use of buffer zones.

E. Prediction Models

1. Numerical mathematical models with digital-computer solutions for the prediction of pressure fields, hydrodynamic gradients, and nature and shape of interfaces in complex, non-homogeneous and anistropic formations.

2. Methods for collection of data on waste movement and behavior, to enable checking of model predictions.

F. Heat Dissipation

1. Heat from radioactivity of waste

2. Heat produced by chemical reactions

CHEMISTRY

A. Waste Classification

1. Detailed quantitative criteria for classification of liquid industrial waste.

B. Compatibility Problems

1. Methods and equipment for sampling and testing of formation fluids under subsurface conditions of temperature and pressure.

2. Chemical interactions of various wastes with various types of formation fluids and formation rocks under subsurface conditions.

3. Chemical interactions between incompatible wastes in intersecting zones of influence of closely-spaced wells.

4. Changes in permeability resulting from various chemical reactions.

5. Waste conditioning to prevent incompatibility reactions.

C. Chemical Modification of Contaminants

1. Attenuation through ion exchange, adsorption, fixation, chemical (or biological) degradation.

2. Formation of, or increase in, noxious properties through chemical degradation of formation of new compounds.

TECHNOLOGY

A. Well design and construction methods.

B. Long-term corrosion resistance of construction materials.

C. Waste-conditioning installations.

D. Monitoring installations.

1. Pressure and chemistry transducers for installation in observation wells.

2. Alarm and automatic shut-off systems.

WASTE MANAGEMENT AND ECONOMICS

A. Reduction of waste volumes through modification of production processes.

B. Processes for waste treatment that enable recycling, or re-use of waste constituents.

C. Techniques for economic optimization of waste management (alternatives including subsurface disposal):

1. on a plant basis,

2. on an industry-wide basis,

3. on a society-wide basis.

D. Techniques for including environmental damage, resulting from pollution, into economic-optimization models.

E. Waste management as part of the management of natural resources.

Section 7

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Land Use/Water Quality Relationships in the U. S. Great Lakes Basin
Task A: To assess problems, management of programs and research...
Category A17 - Management and Control of
Land Use/Water Quality Problems

THE MANAGEMENT OF LAND USE ACTIVITIES WHICH AFFECT WATER QUALITY IN THE GREAT LAKES BASIN

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SECTION 1

Summary

1.1 Introduction

This report discusses the current status and direction of State regulations controlling non-point source pollution from various land use activities. Non-point source pollution controls are presently receiving significantly less attention than point source control efforts. This is primarily due to limited data and knowledge about non-point source pollution, and to the fact that most State programs are currently directed towards documented forms of significant environmental degradation, namely, point sources. This problem can be partly remedied by collecting the necessary data. Such information will provide a basis for recommending priority programs for solutions to the non-point pollution problem.

As point source control programs continue to limit pollutional emissions, non-point source pollution will become relatively more significant, with State regulatory guidelines and practices increasingly addressing non-point sources in the future.

Variations in State level regulations concerned with non-point sources of water quality degradation among the Great Lakes Basin States were noticed with respect to certain land use activities. These primarily reflect the variations in problem assessment depending on the severity of various activities in specific geographical areas. Generally one can say that disposal operations--liquid, solid, and subsurface injections--are major focal points of State level regulations. In addition pesticidal controls are fairly well developed. However, erosion and sedimentation and nutrient residual materials are regulated in widely varying degrees in the Basin area, depending on the problem assessment at the State level.

Following are the major management concerns with respect to non-point source pollution control:

(1) fostering land-use practices which can reduce land drainage of polluted materials to ground and surface waters

(2) gaining an understanding of the impact of land-use activities on ground water

(3) developing regulations which are both acceptable and effective in controlling non-point source pollution

1.2 Summary of Findings and Conclusions

The findings of this report fall into three categories. The first finds that the general management of land-use activities which generate non-point source pollutional loadings to surface and ground water has centered mainly on voluntary land use management guidelines, supported by public extension services and educational programs. Most States in the Great Lakes Basin have not established land-use regulations directly concerned with non-point source pollution. However, as population increases in the Great Lakes Basin and land is placed under increasingly intensive use, there will be a greater need to regulate land-use practices to prevent significant environmental degradation. Activities in this direction are in the preliminary stages of research and development, including draft formulation in some states.

The second is the need to address the types of residual materials generated from non-point sources: sedimentation, nutrients, pesticides and herbicides, as well as certain other materials. Almost all land-use activities release one or more of these residual materials. Currently all States possess pesticidal controls. Only three States, however, have specific statutes regulating erosion and sedimentation from land-use activities, and only two States have statutes dealing with nutrient wastes, specifically from intensive animal feedlots.

The third is the likelihood that in some instances methods for collecting and treating non-point source runoffs are feasible, in other words, the transformation of non-point sources into point source runoffs which then can be treated and disposed of. Such programs include storm water treatment systems and disposal facilities with leachate treatment. The problem in this area is not the lack of State authority, since most disposal operations come under direct State regulatory practices, but the lack of an adequate monitoring and surveillance system for operational procedures to insure that suitable construction practices are followed. The State must also provide specific regulations over what can and cannot be leached from disposal sites. Because of the cost of this approach, it is questionable that it will be publicly acceptable and enforceable except in limited cases.

Preventive methods rather than restoration of damaged ecological balances are an essential element in regulating non-point source pollution. There are also advantages in changing basic manufacturing processes to reduce their various waste residual emissions. This is a highly economical means to reduce pollution loading on waters, not only from an industrial point of view, but also from a regulatory point of view. By changing manufacturing processes in this manner, the outflow of residuals can be altered to become more compatible with ambient standards, thus reducing monitoring and surveillance costs and reducing the effective costs of providing "end of the pipe" treatment. However, there have been few attempts to provide industry with incentives to alter their production processes to reduce emissions which can degrade water quality. Incentives could include tax programs, assistance to small businesses, as well as an intensive educational effort. This is an area for evaluating the policies and procedures that governmental agencies could take to foster changes in production processes that would be compatible with water quality goals.

This is especially important in areas where land and water systems interface, such as erodible shoreline zones and areas subject to sheet and gully erosion. Most research to date indicates that land-use zoning which takes into account the impact of land use on water will be necessary in order to provide a significant measure of control over non-point source pollution.

In reviewing non-point source pollution this study did not look at radioactive waste materials. This is, however, an important category which requires further research to assess the magnitude of radioactive leakage released through spills. Generally radioactive materials come under Federal legislation and control, but States could become involved with regulating the transport of radioactive materials in intrastate commerce to reduce potential hazards. Unfortunately, there is limited information about the actual impact of radioactive spills on the environment. Further study is warranted on the effects of radioactive spills with emphasis on the transport of radioactive materials.

SECTION 2

Introduction

2.1 General

Historically, the management and control of water quality has been directed primarily at reducing effluent loads from point source discharges. Point source discharges are generally defined as discharges from an identifiable, discrete outflow such as an "end-of-pipe" municipal sewage discharge into a waterway. This approach has been based on the assumption that the severest man-induced forms of water degradation originate from point sources. Therefore, in allocating scarce environmental resources, point source control methods have usually been given the highest priority. However, as point source control programs increasingly improve the quality of effluent discharges, diffused non-point sources such as agriculture, silviculture, mining, construction, and subsurface excavations will become relatively more important in water quality management. In recognition of this, the Federal Water Pollution Control Act Amendments of 1972 (P.L. 92-500), Section 304(e), indicates the need for attention to non-point source activities (52).

A primary goal of P.L. 92-500 is correcting informational deficiencies surrounding non-point source pollution. Over the next two years, each State will develop a profile of its non-point source problems and assess prevention and control techniques necessary for its particular set of non-point source problems (52). During this period the primary responsibility in these research areas is assigned to the U.S. Environmental Protection Agency.

The goal of the 1972 amendments is to have local and State non-point source pollution control programs implemented within three years in order to achieve the 1980 ambient standards. The Act combines treatment and preventive management techniques at the local level and legislative movements at the State level to promote land-use practices addressed at non-point source pollution prevention.

The linking of non-point source pollution control and land-use management is significant because land-use management techniques form the only feasible method for realistically controlling non-point source pollution, especially with regards to ground-water quality.

P.L. 92-500 specifically points out that non-point source pollution control is basically a State problem. States are viewed as being responsible for planning and implementing any activity concerned with non-point source pollution. The Federal government is primarily responsible for providing technical and monitoring assistance, except in the case of Federal lands where Federal control will be emphasized.

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Another aspect of non-point source pollution control via land-use management is that most land-use activities will vary in their impact upon ground-water and surface water areas, depending on soil conditions and other features. Thus, all else being equal, intensive farming activities on steeply sloping terrains will affect stream sedimentation more than activities of a similar nature on flat or gently sloping lands. Regulations controlling land-use activities should take land characteristics into account, deeming which features are best suited to certain activities, and then exploit these physical characteristics to their fullest. Unfortunately, this procedure has not as yet been adopted by most of the States.

Federal land management proposals such as the proposed Land Use Planning Assistance Act (HR-10294) are not aimed specifically at non-point source pollution control. However, they do address the interrelationship between land use and environmental quality to some degree.

Throughout the Basin most of the States have, at one time, contemplated land use control measures either at the administrative or legislative level. However, most of them have not developed any comprehensive State level legislation controlling land use with regards to water quality goals.

If land-use legislation includes regulation of various nutrients and pesticidal matters applied to the soil and curtailment of certain activities which result in excessive sedimentation and erosion, then significant progress may be possible in controlling non-point source pollution. However, few land-use management bills, either in the Basin area, or at the national level, have pollution control goals in their frameworks.

The management of coastal zones will inevitably have to address the problem of land use and its interface with shoreland erosion. Therefore, the States could take the initiative in this area and incorporate non-point source pollution of the Great Lakes from shoreland activities into their coastal zone management programs. However, these programs are still in the development stage, and their evolution is at present unclear.

Because non-point source pollution control must coincide with other planning concerns--land use, transportation, social-economic, and point source environmental planning--States will have to increasingly coordinate their water quality management planning with other institutional management planning programs. In recognition of this need, Pennsylvania has developed a Comprehensive Water Quality Management Planning Program (COWAMP) which attempts to coordinate the various levels of State planning as part of an overall environmental design. As provided by the amendments of the Clean Streams Law, the Department of Environmental Resources in Pennsylvania has shifted priorities from pollution abatement to pollution prevention and is attempting to encompass all elements of waste-water management including point and non-point sources of pollution. COWAMP is designed to improve water quality management planning and has as its constitutional basis Article 1, Section 27 of the Pennsylvania Constitution, the Environmental Amendment which states that "people have the right to clean air, pure water, and to the aesthetic values of the environment."

Therefore, the COWAMP Program has a significant institutional legitimacy which seems to be unique in the Basin area. COWAMP initially will focus its non-point source management program on identification and evaluation of the nature and extent of non-point source pollution. Regulatory action will probably be the primary control mechanism in providing preventive solutions to land drainage.

The management of non-point sources must address itself to at least four main pollutants of water quality: sedimentation, pesticides and herbicides, nutrients, and industrial chemicals. Unlike point source programs directed at treating collecting effluents before disposal, non-point source control and management programs cannot presently deal with most non-point source generated residuals in this manner. Management strategies must, therefore, either find a way to reduce the generation of non-point residuals, or improve instream water quality levels after degradation from non-point sources. This requires a departure from traditional point source control programs: The U.S. EPA has formulated a set of guidelines and practices for certain non-point source activities, such as mining, agricultural, silvicultural, and construction activities. Various States have also provided means to control these land-use activities in order to reduce their impact on water quality.

2.2 Scope of the Study

A considerable body of literature exists describing alternative management capabilities and functions for addressing water quality management. For the purpose of this study, material which treated State level management operations concerned with non-point sources was emphasized. In this regard heavy reliance was placed on research activities and reports produced by universities in the eight Great Lakes States, governmental publications outlining State and Federal programs in water quality management, the various reports produced in the other U.S. Task A reports and reviews of articles dealing with water quality management emphasizing the implementation of the 1972 Water Quality Amendment into institutional and management arrangements, either at the State or Federal level. State level policies and programs were viewed, and only those institutional and procedural arrangements which directly incorporated managing land-use activities to control their impacts on water quality were incorporated in the report.

Literature before 1972 usually gives an outdated view of institutional and management practices. However, for some activities an updated profile was not possible. Certain activities, such as sedimentation control, will be significantly revised in the management strategies of various states by the end of 1974. Thus, this study will concentrate on activities from 1972 to 1975.

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2.3 Study Procedure

Various sources of information were utilized. For a general background of State management and control procedures in the environmental field, the Great Lakes Basin Framework Study, Appendixes F20 and S20 (14) were used. Information about specific State programs aimed at controlling point and non-point sources was culled from reports generated by the various State departments dealing with water quality and land-use management. Findings of the reports for Task A, "Study on Great Lakes Pollution from Land Use Activities," (22) were used to generate specific information about legislation and control practices concerning land-use activities in the Basin States. Direct interviews with various State agencies in the Great Lakes Basin helped to update information. Other information came from the recent series on non-point source control practices for certain land-use categories published by the Environmental Protection Agency within the past year, as required by the Federal Water Pollution Control Act Amendments of 1972. In addition abstracts from the Office of Water Resources Research were utilized. Written information pertaining to model legislation and procedures affecting non-point source control were received from agencies such as the U.S. Soil Conservation Service and from various publications on behalf of the Sea Grant Program which coordinated land-use management with water quality control practices.

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SECTION 3

Land Use

3.1 General Description of Land-Use Category

In the past non-point source regulations have included State formulation of standards and guidelines designating certain land-use practices which were not enforceable. Another form of managing and controlling non-point sources has revolved around technical assistance and educational programs from such agencies as the U.S. Soil Conservation Service, assisting local Soil and Water Conservation Districts, and through State universities' agricultural extension services, and in some instances, through various State departments which carry out guidance and informational programs in assisting agricultural and commercial interests to adopt various land-use management practices. For most States, activities which specify procedures for handling non-point source loadings, such as sedimentation and animal wastes, have taken place at the local level.

3.2 Length of Time Activities in Practice

The U.S. Soil Conservation Service's programs directed at erosion and sedimentation control on agricultural lands and local Soil and Water Conservation District programs with assistance from SCS have been in existence for at least two decades. Land-use control, such as deepwell disposal regulations, have been in existence since the past decade in certain States and since 1950 in others. State regulations backed up by enforcement standards have come into general existence only during the past decade, and existing management and control patterns among the eight Great Lakes States are changing.

3.3 Types and Natures of Pollutants Associated with Land Uses

The four basic types of pollutants associated with most land-use activities are nutrients, pesticides and herbicides, sediments, and in some cases, certain industrial chemical wastes found in deepwell disposal operations. While other types of pollutants such as radioactive wastes exist, these are the four major forms usually associated with non-point sources. In future studies, it is recommended that radioactive materials be included in non-point source research to the extent possible.

3.4 State-of-the-Art in Assessing and Quantifying Management and Control Problems

There are many studies dealing with management and control of environmental problems. Emphasis has usually been on point source control, where one can provide procedural steps to reduce the generation of wastes, modify wastes once generated through treatment systems, provide disposal methods which can release these materials at certain rates, times, and locations, and finally modify the assimilative capacities of the environment, such as augmenting stream flow patterns.

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For non-point sources, however, generation reduction has not been considered feasible for most land-use categories. The major areas for management and control of non-point sources revolve around preventing the non-point source pollutants from reaching ground or surface waters. In effect, this forms a method for regulating the disposal of these residuals rather than curbing the generation or providing treatment.

There is considerable controversy concerning appropriate methods for controlling non-point sources. Few studies have dealt with the relative benefits of formalized State regulatory statutes which define the procedures to be accomplished prior to any land-use activity versus an informal administrative code which decides on the measure to be applied prior to land-use activity on a case-by-case basis. For example, Michigan has formulated sedimentation control laws and has pointed out the benefits of informing the public of the sedimentation controls necessary prior to various land-use activities. It is felt that most contractors and developers can begin to alter their procedures to conform with these regulations without involving significant administrative efforts at the State level in attempting to deal on a case-by-case basis. It is also felt that State statutes are stronger in points of jurisprudence than administrative codes.

However, states such as Indiana and Wisconsin have felt that discretionary, administrative powers can be used on a case-by-case basis to tailor land-use procedures to specific circumstances. This allows flexibility in administrative spheres and gives recognition to the difficulty in formulating general non-point source regulatory measures applicable to all situations in the State. Concerning the legal aspects, these States feel that clearly defined rationales for requiring certain measures to be undertaken will allow application of enforcement measures to compel compliance to administrative regulations.

There is also the issue whether State or local action is the proper vehicle with respect to land-use controls. Among the eight Great Lakes States, there seems to be general agreement that State level action is required to bring about regulation of non-point source pollutants.

Another issue concerns whether non-point source programs should rely principally upon generating voluntary compliance or have provision for strong legal enforcement of approved land-use practices. One major drawback in administratively developing strong regulatory procedures is the difficulty associated with monitoring land-use practices and providing sufficient enforcement personnel to compel compliance. Furthermore, the financial resources to implement this type of program are not feasible in the near future. The least costly and most beneficial method lies in generating voluntary compliance to suggested land-use management practices. However, various methods to achieve this may not be effective, depending on the individual situation. For agricultural land usage it is the general feeling among the States that voluntary compliance is essential and local control over implementations of non-point source control procedures must be established. For industrial activities such as extractive land usages and deepwell disposal operations, it is generally assumed that the States must take strong enforcement roles to regulate these practices.

3.5 Probable Changes in Land-Use Activities Management in Time, 1976, 1980, 2020

As programs concerned with non-point source control increase in importance, States will become more involved in land-use planning and management in order to gain leverage over these "background" pollutional effects on water quality.

Because many land-use activity patterns will change to more intensive forms in the future (such as concentrated animal feedlots), State programs will be required to increase their regulatory roles. Even now forestry activities are developing into multipurpose use areas--recreational, silvicultural, wildlife preserves--and in the aggregate they can have significant influences on water quality.

3.6 Projected Seriousness of Future Management and Control Issues and Problems Derived from Land Use Activities

Problems may occur in attempting to develop sufficient State level departmental staffing to generate the necessary procedural steps and implement them. However, the major difficulty will be in changing historical habits of land uses and insuring that people voluntarily comply with proposed land-use management practices. This will involve significant funding for educational and extension programs, increasing State support of staffing services and development of acceptable State land-use management programs.

3.7 Review of Institutional Arrangements to Regulate Land Use for Controlling Water Pollution

3.7.1 Residential and Commercial Areas

New construction sites in urban areas can exert a non-point source loading of sediments up to 500 times greater per unit area than is evident in agricultural operations (22-A7). Urban areas are also significant non-point sources for nutrients and chemical toxins. However, the major type of pollution from non-point source runoff in urban areas is sedimentation, and this results primarily from construction practices. Construction is an extensive land disturbing activity and places urban lands under significant pressures and unstable conditions, resulting in a high loss of top soil. In Michigan and Pennsylvania erosion and sedimentation regulations specifically pertain to sediment runoffs and designate that contractors shall submit plans outlining measures conforming to reduce erosion and sedimentation from their operations as provided in State statutes. In the erosion and sedimentation control program in Michigan, urban construction sites will be the first priority (27).

While the other six States in the Basin do not have specific erosion and sedimentation control ordinances, they can enforce abatement of sedimentation in situations where specific activities can be shown to cause degradation of surface waters under general water quality protection standards.

In previously developed areas sedimentation production tends to be low compared to yields generated from new construction sites. This is due to higher proportions of impermeable surfacing in high density urban areas. The major forms of sedimentation in these areas result from sediment-laden runoff from street and road debris which either drains into storm sewer systems or directly to surface waters. Atmospheric debris produced from transportation, commercial, and residential sources also generates significant particulate fallout into surface waters.

State programs dealing with these aspects of urban sedimentation revolve around air pollution regulations concerned with particulate reduction and the construction of combined or separated storm and sewer systems which can transmit street debris into treatment systems or directly into receiving waters. However, the provision of storm drains and sewers acts as a collection method for non-point source residues, but does not generally aid in improving water quality.

In urban areas significant amounts of pesticides are applied noncommercially, except in the case of controlling Dutch elm disease and mosquitos. Thus, pesticides and herbicides elude management and control programs which have been historically directed at regulating commercial usage.

Nutrients are also an important non-point pollutant in urban areas and are derived from two specific point sources. Animal wastes in urban areas can be a significant form of nutrient waste in the aggregate. Household pets, stray animals, and commercial animals, such as watch dogs, are responsible for substantial quantities of solid and liquid nutrient wastes which flow directly into storm/sewer collection systems, or leach out into the soil. So far control of animal wastes in urban areas has been a local responsibility and usually comes under procedures for insuring that animal owners remove animal wastes from public places and dispose of them in appropriate locations, such as sewage or solid waste collection systems. This would not come under State purview at the present time in the Basin area unless an adverse public health situation arose from inadequate handling of animal wastes.

Combined storm/sewage systems are another aspect of urban runoffs. As one report pointed out, "The frequent transport of storm drainage and municipal waste in the same conduit may allow for the discharge of highly pollutional raw wastewater during periods of extreme runoff," (22-A1/A2). The major problem with combined systems occurs during high storm runoff periods. Most sewage treatment systems do not possess the capacity to handle the increased loads generated in the drainage systems, thus causing significant overflows of raw, untreated sewage mixed with urban stormwater runoff into streams without treatment. Because of this situation, separated storm and sewage systems have been suggested and adopted in many places. However, recent studies have shown that storm water alone contains relatively high levels of pollutional materials, and without proper treatment of stormwater flows, significant deterioration of receiving waters can result. Only Michigan has a State policy forbidding the development of combined systems.

Whether separated or combined, stormwater collection systems might provide at least primary, if not secondary treatment. Again, most States do not have a policy or detailed management and control strategies in this area. Presently local governments are responsible for storm drains (14). However, the provision of treatment capacity for stormwater runoff at high volume levels seems particularly appropriate for policy formulation at the State level (6).

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TABLE 1 Description of State Activity*--Residential/Commercial Areas

	Ill.	Ind.	Mich.*	Minn.	N.Y.	Ohio	Pa.*	Wis.
a policy on controlling residential non-point source runoffs in urban areas			●					
programs for treating residential runoff								
incentives to improve cooperative efforts in this regard								
a monitoring and evaluation program to estimate residential runoffs impacts on water quality			●				●	
standards and regulations controlling residential activities which affect runoff								
enforcement procedures							●	
regulations on construction methods and activities			●				●	

● currently operating

* only Michigan and Pennsylvania responded to questionnaire

TABLE 2 Evaluation of State Activity--Residential/Commercial Areas

	Ill.*	Ind.	Mich.	Minn.*	N.Y.	Ohio	Pa.	Wis.
magnitude of problem								
serious			●				●	
moderate		●			●			●
low						●		
not detectable								
priority given to problem								
above average			●				●	
average								
low		●				●		●
very low/non-existent					●			
current State activity								
legal statutes			●				●	
administrative rules							●	●
public policy formation								
incentive programs								
no action		●			●	●		
likely future State activities								
legal statutes								
administrative rules			●					
public policy formation								●
incentive programs			●					
no action		●			●	●	●	

*no information available

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3.7.2 Transportation

Because most transportation facilities come under different public jurisdictions, State level management and control has been limited to transport facilities such as State highways and public utilities. Likewise, State regulations tend not to apply to interstate facilities, such as railroads or airports, which come under the Interstate Commerce Commission's purview, and thus are subject to Federal rules and regulations concerning their environmental impact and responsibilities under the U.S. Environmental Protection Agency's statutes and procedures. Nevertheless, there are many roads, municipal airports, and intrastate utility lines, which in the aggregate may be significant non-point sources of residual loadings onto surface waters in the Basin area. However, this is not presently documented.

Transportation affects water quality through runoffs to surface water from highways and airports, oils and salts leaching into adjacent soils, herbicidal applications along roadside and railroad sites, and accidental spillage of materials. Certain forms of solid waste such as litter or debris are also found near highways and railroads, but nutrient loading is seldom an important runoff from transportation.

Throughout most of the eight Basin States, there have been few State level management proceedings to regulate non-point source aspects of highways, railroads, or utility lines, except as they may be affected by general regulations controlling pesticides and herbicides, sedimentation, and possibly certain requirements limiting solid waste disposal activities (35). The fact that environmental impact statements (EIS) for new transport construction starts address these issues deserves our attention, for by utilizing EIS procedures, States can begin to require preventive measures limiting the drainage of these materials to surface and ground waters.

Under herbicide regulations, States can limit certain herbicides, such as 2, 4, 5-T, from being used along roadsides or railroad right-of-ways for controlling vegetation where the application may endanger the quality of surface water areas. This can also apply to airport applications and utility transmission line locations where the application of herbicides can leach into the soil and affect surface and ground-water areas.

In the States with sedimentation control procedures, such as Michigan, Ohio, and Pennsylvania, erosion resulting from the construction of transport systems, such as highways, railroads, airports, and utility lines, can be limited in order to avoid excessive sedimentation. In fact, Michigan's plan for soil erosion and sedimentation control recognizes the potential for these land-use categories to generate significant sedimentation loads and specifically includes transport land-use activities as requiring sedimentation control plans (27). In the five other States voluntary advisory channels are available to provide temporary impoundments at highway construction sites to prevent siltation of waterways. Yet, voluntary actions alone may not be sufficient to curb sedimentation.

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Runoffs of salts, sand, and oils are other examples of highway non-point loadings. There are currently few programs among the eight Great Lakes Basin States to control these forms of surface runoffs from road systems. Oil seepage from automobiles can leach into the soils and affect either surrounding surface-water areas, or slowly degrade ground-water quality. Likewise, seasonal applications of salts can leach off in the springtime and affect surface-water quality. While there are few substitutes for salting roads in the wintertime to prevent icing, most States attempt to minimize salting.

Herbicide applications to roadside areas to curb vegetation come under general pesticide application laws at the State level. Nutrient loadings generated from application of fertilizers to roadside strips of vegetation is not seen as a significant problem in most cases because of the limited nature of this activity. Currently, there are no programs for curbing or regulating fertilizer applications.

The major forms of erosion and sedimentation from railroads occur in the construction of tracks. However, this is not a significant activity at present and has not been an important factor for State water quality control. At the present time the emphasis lies in controlling certain herbicide applications from being used near adjacent surface-water areas (1). There are no controls for sedimentation from already existing railroad lines, or for possible runoffs of oils or other compounds produced in railroad operations.

Substantially, the same picture exists concerning airports where few, if any, State regulations address the impact of airports' non-point pollutional impacts upon water quality. It does not appear that in the near future the transportation land use sector will be receiving attention at the State level in addressing their non-point impacts on water quality outside of management and control proceedings applied to new construction starts which may be incorporated under sedimentation programs or programs regulating herbicide and pesticide applications.

TABLE 3 **Description of State Activity--Transportation**

	Ill.	Ind.	Mich.*	Minn.	N.Y.	Ohio	Pa.*	Wis.
evaluations of road runoffs on surface and ground water quality								
measures to reduce road runoffs			●				●	
monitoring of runoff water								
regulations controlling airport runway runoffs								
monitoring airborne residues which affect water quality from transport activities								

● currently operating

* only Michigan and Pennsylvania responded to questionnaire

TABLE 4 **Evaluation of State Activity--Transportation**

	Ill.*	Ind.	Mich.	Minn.*	N.Y.	Ohio	Pa.	Wis.
magnitude of problem								
serious								
moderate			●					
low		●			●	●	●	●
not detectable								
priority given to problem								
above average								
average							●	
low		●	●					●
very low/non-existent					●	●		
current State activity								
legal statutes			●				●	
administrative rules			●				●	
public policy formation								
incentive programs								
no action					●	●		
likely future State activities								
legal statutes								
administrative rules								
public policy formation								
incentive programs								
no action		●	●		●	●	●	●

* no information available

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3.7.3 Extractive

Depending on the nature of the extractive operation, State regulations and control procedures vary. Regulations concerning oil and gas wells emphasize preconstruction review, especially on State lands, and control procedures for the abandoning and capping of wells. State regulations concerning surface mining are more extensively developed and involve procedures requiring reclamation of land, backfilling, grading, and planting requirements, as well as preventing degradation of ground water by mines. Comparatively few States regulate underground mining operations in the area of water quality control because of the relatively few operations of this nature. The exception to this is in cases where acid mine drainage has become a significant problem in Pennsylvania (39) (22-A4).

In subsurface mining operations regulatory procedures can set requirements for abandoning the operations. This could mean sealing the entrance and allowing it to fill with water. Most States currently do not require the filling of mines to prevent acid drainage, except for Pennsylvania where acid mine drainage is a significant contributor to the degradation of water quality. It is almost impossible to prevent ground water from seeping into subsurface mining operations, and until recently, the serious effect of acid mine drainage on ground water and aquifer water quality was not regarded as being significant enough to expend State manpower and resources to control it.

Oil and gas drilling regulations vary among the Basin States concerning drilling beneath inland waters. Only Michigan, Ohio, and Pennsylvania have policies discouraging this type of operation, although all the States except Wisconsin have statutes controlling mining operations beneath the waters of the State. These statutes cover construction standards, surveillance requirements, and the drilling and operating of dewatering wells. Only New York and Pennsylvania have requirements specifying the drilling and operating of dewatered wells. All Basin States require that wells be capped and filled on abandonment to prevent seepage of ground and surface water into the wells and possible backflows of fluids from the wells onto surface-water areas.

Surface mining is also controlled differently depending on each State's experience with surface mining operations. The following regulate the effects of surface mining operations upon water quality.

(1) The types of mined minerals covered may vary from State to State. For instance, Illinois and Pennsylvania statutes cover extractive operation of all minerals including coal, clay, stone, sand, gravel, and other materials. Indiana, likewise, applied controls over all minerals. However, Ohio only covers coal extractive operations. In Minnesota and Wisconsin only metallic minerals are covered. In Michigan gravel pits, peat, marle, clay, and stone quarry activities are excluded from surface mining controls but not from its Mine Reclamation Act.

(2) Only Michigan, under its Mineral Well Act and Pennsylvania, under its Erosion and Sedimentation Law control sedimentation and erosion from surface extractive activities. However, in Michigan the general assessment is that the Sedimentation and Erosion Control Act probably will not apply to activities on lands owned by the extractive operations but will only be enforced at the property limits when that operation affects sedimentation loads downstream on other property.

(3) Currently Illinois, Indiana, Ohio, and Pennsylvania require a reclamation plan in order to gain permits for strip and surface mining activities. Michigan currently does not require control dykes or revegetation, although they strongly suggest it.

(4) Illinois, Indiana, Pennsylvania, and Ohio have different viewpoints concerning the requirements of backfilling and grading of strip and surface mining areas. Illinois requires that peaks and ridges be graded and earthdams be constructed. Acid-formed materials must be buried. Access lanes must also be constructed. In Indiana peaks and ridges must be graded when adjacent to public highways and dams must be constructed. Similarly, acid-forming materials must be buried. In Ohio peaks and ridges must be graded, dams have to be constructed to impound water, and acid-formed materials must be buried. In addition runoff water must be impounded to prevent mine drainage and possible forms of sedimentation. Pennsylvania requires peaks and ridges to be cropped and access roads constructed. Rubbage and debris, which contains acid and nonacid-formed materials, must be buried and water must be impounded where lakes and ponds are approved. All four States require some form of bonding to insure reforestation and revegetation for sediment control on surface mining areas. These bonds are refundable when the spoilage has been satisfactorily revegetated with grasses or other forms of vegetation. Usually vegetation is only required on spoil piles, although this has been increasingly applied to open pit areas.

Michigan's Mine Reclamation Act, the major regulatory control procedure for insuring control of water quality degradation from mining activities, places the major emphasis for proving control procedures upon the supervisor of mining operations who must conduct a comprehensive survey and study in order to determine the extent and type of regulation of mining areas necessary in the public interest. The supervisor is the Chief of the Geological Survey Division of the Department of Natural Resources, and among his various tasks, specific emphasis is placed upon the control of erosion and water pollution. The supervisor must promulgate rules pertaining to mining operations which may require among other things revegetation or other practical treatment of tailing basins and stockpiles, the stabilization of surface and overburdened banks, particularly around opened pits in rock and banks of unconsolidated materials upon their abandonment. Finally, he may require the clean-up of plant sites and mine areas at the termination of mining operations. After setting these rules, the supervisor may grant variances on a case-by-case basis. Unlike the other four States, Michigan's approach to controlling mining activities is to provide regulatory procedures at an administrative level under its Mine Reclamation Act rather than through legislative statutes.

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One report summarized that most States' regulatory laws concerning strip mining are weak (49), especially in the area of requiring land restoration. Pennsylvania's strip mining laws are considered perhaps some of the strongest in the nation. However, as the report indicates, they are often undercut by ineffective backup regulations and limited enforcement. One problem noted in Pennsylvania is the practice of some operators forming new companies to avoid the reclamation work required under old licenses. Additionally, there remain problems in abandoned sites which cause landslides, erosion and sedimentation, and acid mine drainage into the receiving waters.

Another problem concerning extractive operations is the difficulty of enforcing regulatory practices where the standards do not provide economic incentives for operators to comply (51). There is also the difficulty in defining the requirements for issuing permits for mining activities. For instance, in Ohio, current laws appear to give the State authority to deny a mining permit if the land cannot be reclaimed. The language is somewhat vague, and until recently, the State has never denied a permit. However, recently permits have been turned down, although this has been appealed. Stronger legislation has passed the Ohio House of Representatives and seems on the verge of passage through the Senate.

TABLE 5 Description of State Activity*—Extractive Land Uses

	Ill.*	Ind.	Mich.	Minn.*	N.Y.	Ohio	Pa.	Wis.
regulates operations		●	●		●	●	●	●
regulates methods of drilling			●		●	●	●	●
requires operation licensing		●	●		●	●	●	●
requires monitors of ground water impacts, and flows							●	●
has a policy on oil drilling below surface waters of State		●	●			●		
has requirement for abandoning mines, wells, etc.		●	●			●	●	●
prescribes construction standards		●	●		●	●	●	●
has State surveillance of operations			●		●	●	●	●
controls mine spoils disposal, location, and revegetation			●		●	●	●	●
requires drainage controls		●	●			●	●	●
provides for reclamation of lands		●	●		●	●	●	●
regulates sludge disposal			●			●	●	●
requires water control and water infiltration control			●			●	●	●

● current activity

* Illinois and Minnesota did not respond to questionnaire

TABLE 6 Evaluation of State Activity-- Extractive Land Uses: Oil, Gas, and Brine Wells

	Ill.*	Ind.	Mich.	Minn.	N.Y.	Ohio	Pa.	Wis.
magnitude of problem								
serious			●				●	
moderate		●			●	●		
low								●
not detectable								
priority given to problem								
above average			●				●	
average		●			●	●		
low								●
very low/non-existent								
current State activity								
legal statutes		●	●		●	●	●	
administrative rules		●	●		●	●	●	●
public policy formation						●	●	
incentive programs								
no action								
likely future State activities								
legal statutes								
administrative rules								
public policy formation								
incentive programs								
no action		○	○	○	○	○	○	○

*no information available

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TABLE 7 Evaluation of State Activity--Extractive Land Uses: Strip-mining and Metallic Sub-surface

	Ill.	Ind.	Mich.	Minn.	N.Y.	Ohio	Pa.	Wis.
magnitude of problem								
serious	●						●	
moderate		●		●	●	●		
low			●					●
not detectable								
priority given to problem								
above average				●			●	
average		●	●		●	●		
low	●							●
very low/ nonexistent								
current State activity								
legal statutes		●	●	●	●		●	●
administrative rules		●	●	●	●	●	●	●
public policy formation			●	●	●	●	●	
incentive programs							●	
no action								
likely future State activities								
legal statutes								
administrative rules								
public policy formation								
incentive programs								
no action		●	●	●	●	●	●	●

TABLE 8 Evaluation of State Activity--Extractive Land Uses: Open Pit, Non-Metallic

	Ill.*	Ind.	Mich.	Minn.*	N.Y.	Ohio	Pa.	Wis.
magnitude of problem								
serious								
moderate							●	
low		●	●		●	●		●
not detectable								
priority given to problem								
above average								
average		●	●		●		●	
low						●		●
very low/non-existent								
current State activity								
legal statutes							●	
administrative rules		●	●		●	●	●	
public policy formation							●	
incentive programs								
no action								
likely future State activities								
legal statutes								
administrative rules								
public policy formation								
incentive programs								
no action		●	●		●	●	●	●

*no information available

TABLE 9 Summary of Statutory Regulation--Extractive Land Uses

	Ill.	Ind.	Mich.	Minn.	N.Y.	Ohio	Pa.	Wis.
Are construction standards prescribed by statute?			yes			yes	yes	yes
Is State agency surveillance required by statute?			yes		yes	yes	yes	yes
Does the State have regulations covering drilling and operating of dewatering wells?				yes	yes, on Long Island only		yes	
May State lands be drilled upon by private individuals?		yes,for oil/gas only	yes, by special permit		yes,for oil/gas only	yes	yes, by special permit	---*
Does the State have a statute expressly controlling mining beneath the waters of the State?	yes	yes	yes	yes	yes	yes, under Lake Erie only	yes	
Are all waters covered by the statute(s)?	yes	no**	yes	yes			yes	
Is there a strong State policy regarding oil drilling beneath the waters of the State?			yes			yes	yes	
Must abandoned wells, test holes, and oil wells be filled, capped, or plugged?	yes	yes	yes	yes	yes	yes	yes	yes
Are any persons, areas, or minerals exempted from operation of the statute?				yes	yes, private lands			yes
Are there any specific laws controlling mining drainage?			yes	yes		yes	yes	
Are there State controls regulating sand and gravel excavations for the protection of ground-water resources?			yes	yes			yes	
May water be diverted between basins for mining purposes?			yes, by State permit only			yes,in practice	yes	yes
Are there any special statutes modifying common law water rights relating to mining and drilling?			yes	yes			yes	yes

* issue has never arisen

** public fresh-water lakes only

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TABLE 10 Comparison of Strip and Surface Mining Laws (1967)

State	Code citation	Coverage	Number of agencies administering laws	License requirements		Penalty for failure to obtain license	Bond required	
				Basic fee	Additional fee per acre		Minimum	Additional bond per acre
Illinois	93 Ill. Stat. Ann. 180	All minerals	1	(1)	None	$50-$1,000 fine	$1,000	$200 over 5 acres
Indiana	Ind. Stat. Ann. 46-1501	All minerals	1	(2)	None	$1,000-$5,000 fine	2,000	$300 over 5 acres
Ohio	Ohio Rev. Code §1513	Coal	2	75	$15 per acre of land to be affected in license year	$300-$1,000 fine	2,000	$300
Pennsylvania	Pa. Stat. Ann. Title 52, §1396 (anthracite) Title 52, §1396 (bituminous)	Coal	2	300	None	$5,000-$10,000 fine or 6 months imprisonment or both	5,000	$500

	Maps and reclamation plan required	Backfilling and grading requirements	Replanting requirements	Substitution of lands to meet reclamation requirements permitted	Mining and reclamation reports required	Penalty for failure to reclaim		Special reclamation fund established
						Forfeiture of bond	Denial of new permit	
Illinois	Yes	(3)	Yes	Yes	Yes	Yes	No	No
Indiana	Yes	(4)	Yes	Yes	Yes	Yes	Yes	No
Ohio	Yes	(5)	Yes	Yes	Yes	Yes	Yes	No
Pennsylvania	Yes	(6)	Yes	No	Yes	Yes	Yes	No

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(1) Variable, depending upon acres to be disturbed, i.e., 10 acres - $50 basic fee plus $11.50 X number of acres between 2 and 10 acres annually.

(2) Variable, depending upon acres to be disturbed, i.e., 10 acres - $200 fee, 100 or more acres $500 fee annually.

(3) Grade peaks and ridges to a rolling topography; construct earth dams in final cuts; bury acid-forming materials; construct fire lanes and access roads in afforested land.

(4) Peaks and ridges must be struck to a rolling topography adjacent to public highways; construct dams in final cuts; bury acid-forming materials

(5) Grade peaks and ridges to rolling topography; construct dams to impound water; bury acid-forming materials; impound runoff water; construct fire lanes or access roads.

(6) Grade peaks and depressions to a rolling topography; construct access roads; bury refuse and debris; impound water for lakes or ponds where approved.

exerpted and adapted from U.S. Department of the Interior, Surface Mining and Our Environment, 1967, Appendix II, p. 120.

1 Acre = .40469 Hectares

3.7.4 Impact of Agricultural Use of Pesticides on the Water Quality of the Great Lakes

During the past several decades pesticide usage has increasingly come under regulatory practices, both at the State and Federal level. This has been in recognition of the potential effect that pesticides have upon animal and plant life in both aquatic and land ecosystems. The general movement is towards user restrictions through labeling to control the dissemination and application of pesticides. Because of the beneficial roles pesticides can play in controlling harmful pests, most States have been reluctant to provide outright bans on various categories of pesticides. However, there has also been a reluctance to allow unrestricted use of those chemicals which have been determined as being highly toxic and accumulative in the environment.

State management and control of pesticides range from outright banning of certain pesticides, mainly the chlorinated hydrocarbons, to restricting areas of pesticide usage. Most States do not regulate household pesticide applications, but limit their regulations and procedures to commercial applications.

Most of the controls concerning pesticide applications and limitations upon their use involve their effect upon ecological balances. Pesticide applications are also limited to prevent deterioration of water quality. In regards to water quality orientated control of pesticides, however, there are few regulations at the State level. What regulations exist deal with limiting or prohibiting direct pesticide applications into surface waters. These prohibitions are usually applied during the issuance of commercial pesticides applications permit (22-A5).

Wisconsin regulates the effect of pesticides on water quality by issuing permits for application on a case-by-case basis and applying restrictions pertaining to aspects such as controlling for drift during high winds, stopping application operations if drifts do occur from aerial spraying of herbicides and pesticides, and regulating the distance from receiving water areas, such as streams and rivers, to provide a buffer zone between areas of application of pesticides and surface-water areas.

However, few States have statutes aimed at regulating pesticides' and herbicides' water quality impacts except in the area of their disposal (14). In this instance some States do regulate, through specific statutes, the means for disposal of containers and excess pesticide materials. Wisconsin demands that pesticide containers be buried in the ground or disposed of in a sanitary landfill (56). Excess pesticide materials can only be disposed in nine designated landfill sites throughout Wisconsin or in one or more designated chemical waste incinerators.

Regulations that control the application and location, as well as the amounts of pesticides to be employed, will affect pesticide impacts on water quality. Table 13 lists the various types of management procedures used by the States to regulate pesticides.

Research has indicated that pesticide residuals that come into contact with water usually settle into the bottom sediments of streams and ponds and may or may not enter the food chain once in bottom sediments. In cases where individual States have developed monitoring practices for pesticide residuals, few studies have found any significant concentrations of pesticides in either aquatic or land environments. Information is currently inconclusive about the long-range effects of pesticide applications. Nevertheless, most States are attempting to apply more stringent controls, specifically in the types of pesticides which can be applied by unlicensed operators. Few State are banning pesticides. Rather, most are insuring that the application of restricted pesticides, i.e., those which persist once distributed in the environment and are highly toxic to plant and animal life, are applied by trained licensed operators to insure minimal contact with forms other than those for which the pesticides are designated (1).

Currently all Basin States require registering of commercial pesticides and regulate the distribution of restricted pesticides by regulating transport methods, retail and wholesale sales, and distribution of permits.

TABLE 11 Description of State Activity--Pesticides and Herbicides

	Ill.*	Ind.	Mich.	Minn.*	N.Y.	Ohio	Pa.	Wis.
registration of users								●
regulations concerning the types and amounts applied on public and private lands		●	●					●
controls regulating the application on or near various land uses			●		●			●
retail and wholesale regulations		●	●		●			●
guidelines concerning disposal of application containers		●	●		●			●
licensing or registration of operators		●	●		●	●		●
a monitoring system for evaluating pesticide impacts on water quality								
an enforcement system		●	●		●	●		●
a system of incentives to foster voluntary compliance with State guidelines								

● currently operating

* Illinois and Minnesota did not respond to questionnaire

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TABLE 12 Evaluation of State Activity--Pesticides and Herbicides

	Ill.*	Ind.	Mich.	Minn.*	N.Y.	Ohio	Pa.	Wis.
magnitude of problem								
serious								
moderate								
low		●	●		●	●		●
not detectable								
priority given to problem								
above average								
average		●	●		●			●
low						●		
very low/non-existent								
current State activity								
legal statutes		●	●		●	●		●
administrative rules		●	●		●	●		●
public policy formation		●			●			
incentive programs		●						
no action								
likely future State activities								
legal statutes								●
administrative rules								●
public policy formation								
incentive programs								
no action			●		●	●		

* no information available

TABLE 13 Description of State Regulation--Pesticides and Herbicides

	Ill.	Ind.	Mich.	Minn.	N.Y.	Ohio	Pa.	Wis.
registry of pesticides	●	●	●	●	●	●	●	●
law regulating								
transport			●				●	●
distribution	●	●	●	●	●		●	●
sales	●	●	●	●	●		●	●
use	●	●		●	●		●	●
restricted use by								
type	●	●	●		●			●
area	●							●
applicator	●		●					
labeling specifications	●		●	●				●
permit use system						●		●
regulations controlling								
storage								●
disposal of pesticides								●
disposal of containers								●
licensing of users								
banning of certain pesticides			●		●			
monitoring program	●	●	●	●		●		●

3.7.5 Nutrients

Agricultural land is estimated to contribute approximately 20 percent of the total phosphorus loading in the Great Lakes and approximately 30 percent of that contributed by tributaries to the Great Lakes (22-A6). Unfortunately, sufficient information is not available to compute the proportion of nitrogen loadings contributed from agricultural lands although it may be similar to the amount estimated for phosphorus.

While there is considerable research and literature available outlining the effects of nutrient loading on stream and water quality, there has not been, at the State level, regulatory measures concerned specifically with controlling nutrient usage on agricultural land to limit their effect on stream and ground water quality. Major organizations to manage nutrient loadings on agricultural soils are State universities' agricultural extension services which advise farmers on the optimal amounts of fertilizers per acre of agricultural lands depending on the types of soils and crops to be grown. Voluntary compliance is the approach used at the present time to reduce nutrient loadings. These programs usually do not counsel or undertake studies on the effects of nutrient loading from agricultural lands to adjacent surface waters, but focus mainly on the economic optimum application rates per area of land surface. There have been few attempts at regulatory action or voluntary compliance in creating buffer zones near streams and rivers where nutrient applications could be proscribed.

Various types of nutrients have different effects on water quality. Additionally, there seems to be few recommendations and guidelines for methods of application, especially in aerial application methods whereby aerial drift of nutrients can come into direct contact with surface waters. However, it is possible for States to limit nutrient effects on water quality through other management procedures, such as floodplain management, land-use zoning practices, land drainage requirements, and erosion and sedimentation control programs. In each of these categories proper management of land uses will affect nutrient loading transport rates to receiving waters. The capability of States to formulate management strategies aimed at reducing nutrient runoff has been constrained by the lack of knowledge concerning the specific interactions between nutrients and receiving waters. This is also true of transport potentials for nutrients from soils to surface water areas through different mediums, such as sedimentation or land drainage systems.

This is further complicated depending on the type of agricultural operations, i.e., whether it be row crops, close-grown crops, pasture and meadows, or orchards and vineyards. Not only is there a lack of information about exact characteristics of the interactions of nutrients and water, but there is also the problem of attempting to regulate thousands of individual users of fertilizers and other nutrients. In Indiana alone with more than 200,000 farms, developing regulations, monitoring, and control practices guiding nutrient applications are not feasible given limitations on available funding and manpower.

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Although the possibility exists of regulating the retail sale of various nutrients, this has not occurred in any of the Basin States. While the regulation of pesticide container labeling is common, this is not done for nutrient containers. One drawback is the difficulty in insuring that labeled containers will be read and followed by individual users.

TABLE 14 Evaluation of State Activity--Agricultural Nutrients

	Ill.*	Ind.	Mich.	Minn.	N.Y.	Ohio	Pa.	Wis.
magnitude of problem								
serious								
moderate		●	●					●
low				●	●	●	●	
not detectable								
priority given to problem								
above average								
average								
low		●	●				●	●
very low/non-existent				●	●	●		
current State activity								
legal statutes								
administrative rules								
public policy formation								
incentive programs								
no action		●		●	●	●	●	●
likely future State activities								
legal statutes								
administrative rules								
public policy formation								
incentive programs								
no action		●	●	●	●	●	●	●

*no information available

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3.7.6 Erosion and Sedimentation

Soil erosion and sedimentation control has existed for some time in the area of agricultural management. Local conservation district, in conjunction with the Federal Soil Conservation Service, have given assistance to farmers in implementing programs to reduce soil loss from erosion and sedimentation which can adversely affect cash crop operations. However, erosion and sedimentation control has been based in the past on economical agricultural practices. The changes in land use evident today place the emphasis on controlling erosion and sedimentation in a different light. Shifts from agricultural activities to urban and suburban land uses, including industrial and commercial development, have tremendously increased land disturbing activities in the United States. The ratio of sedimentation yields between new urban construction sites and rural areas can be as great as 500 to 1 (22-A7).

Various States have moved towards adopting or considering State legislation for soil erosion and sedimentation control which would apply to urban and rural areas. In this regard the Council of State Governments Committee on Suggested State Legislation proposed a model State act for soil erosion and sedimentation control, published by the National Association of Conservation Districts in 1972 (7) (9). Because an estimated 98 percent of all private lands are within soil conservation districts, the model act placed erosion and sedimentation control programs within the district framework as the official implementing agency for State erosion and sedimentation control guidelines and programs. Moreover, it was the district's responsibility in the model act to establish consistent State-wide programs and guidelines for various types of land uses. The key feature, at least in the structure of the model ordinance, was that the State Soil and Water Conservation Commission would be the essential policy-making and guideline-formulating body at the State level. The Commission would also have ultimate determination over the approval or denial of permits for land-use activities which required erosion and sedimentation control measures (9).

Soil Conservation Districts would review all plans submitted to them for erosion and sediment control at the local level with the Soil and Water Conservation Commission acting as a review board and having final determination over their implementation. The model statute would allow monitoring of operations, including on-site inspection and filing of periodic reports of land uses, as well as setting up the possibility of fines or imprisonment for violations of soil conservation plans and procedures issued by the Commission. However, most States have not adopted the model sedimentation law as developed by the Council of Governments.

The management and control of sedimentation is not uniform among the various Great Lakes Basin States. Procedural controls range from reliance on the soil conservation districts in rural areas to assist farmers in adopting land-use management practice, to the development of State-wide statutes and regulations for soil erosion and sedimentation control. However, soil conservation districts aid local farmers in developing erosion and sedimentation control programs in all the States. This mainly affects rural areas and does not have any direct impact on urban settlements, although soil conservation districts tend to operate in this sphere as well (52).

Indiana and Wisconsin are now developing pilot sedimentation control demonstration projects. In Wisconsin a demonstration project is being developed for the Washington County area in conjunction with the soil conservation districts, the State's Board of Soil and Water Conservation Districts, the University of Wisconsin, and the Department of Natural Resources, along with Federal assistance from the Soil Conservation Service. It is hoped that regulations and guidelines can be derived from this project and that the advantages of sedimentation control can be made evident to other areas in the State. In Indiana the Allen County Soil and Water Conservation District in cooperation with the U.S. EPA, the U.S. Department of Agriculture, and Purdue University's extension program, has been developing plans for erosion and sedimentation control to limit the environmental impact of land uses on surface water areas in Allen County and the Maumee basin.

Illinois, Indiana, Minnesota, New York, and Wisconsin do not possess State laws or regulations directed specifically at sedimentation control. In these States land-use activities that generate loads of sediments which could adversely affect water quality in the area can be abated under general water quality guidelines and regulations. Michigan, Ohio, and Pennsylvania are developing specific regulatory programs for controlling sedimentation. Michigan's program currently deals with urban and rural activities and sets out in legislative fashion the types of land uses which are regulated. Pennsylvania has developed a similar program for treating urban and rural sedimentation. However, Ohio's sedimentation control program is primarily limited to agricultural lands, and unlike the situation in Michigan and Pennsylvania, it has not developed clear specifications on the enforcement of its procedural provisions.

The Michigan program for soil erosion and sedimentation control currently has legislation authorizing State involvement with erosion and sedimentation control, but procedural implementation is awaiting further work (27). A completed program for soil erosion and sedimentation control will probably be ready by the end of 1974. Urban erosion and runoff will be the initial priority within this program. Under the Michigan program, local agencies will enforce the sediment control program. A 1979 deadline has been enacted for incorporating rural areas into the program, delaying the full implementation of erosion control measures until that time. Agricultural operations necessitate a conservation plan approved by the soils conservation districts or other recognized agricultural conservation agencies. These plans must provide for soil erosion control from earth-disturbing activities. One reason for distinguishing between urban and rural areas in complying with this Act is the relatively high priority given to controlling urban runoffs which result in major contributions to sedimentation of lakes and streams, as well as the recognition of limited manpower and funding which must first be allocated to the more pressing problem areas.

The situation in the five States without State erosion and sedimentation control programs varies. In Indiana there is no sedimentation control ordinance presently, although the Council of Governments Sedimentation Control Ordinance was explored. No legislative bills were drafted for passage. Sedimentation control is provided by the Soil Conservation Service, which advises counties and individual farmers to adopt their guidelines and procedures. However, the Soil Conservation Service does not have enforcement or regulatory powers. The emphasis is on voluntary compliance only. The Indiana Stream Pollution Control Board can, as part of its responsibilities, demand that certain activities take measures to insure that sedimentation loads will not adversely affect water quality by increasing suspended solids contents or discoloring the water. There have been instances in residential construction operations where desilting pits and debris basins were ordered to prevent siltation of rivers. However, in requesting such procedures, no specific requirements or specifications are made. The only exception to Indiana's voluntary compliance approach is in the area of sand and gravel operations where sedimentation basins are required as part of the permit program.

In Wisconsin, control efforts center on a demonstration program in Washington County. The program primarily involves information exchange and hopes to develop regulatory procedures for reducing sedimentation from land-use activities. It is a multi-agency program and should a State erosion and sedimentation control ordinance be passed in Wisconsin at a future date, interagency cooperative efforts will hopefully continue and insure successful implementation of the program.

Voluntary compliance is stressed in Wisconsin, with the accent upon local participation. Currently counties or local municipalities can pass their own sedimentation control ordinance, and some have done this (56). One of the factors limiting Wisconsin's further involvement in generating State sedimentation programs is the problem of developing new management structures at the State level for regulating and enforcing the program.

It is Wisconsin's view that neither the U.S. Soil Conservation Service, nor the soil conservation districts should be, or would want to be, part of a regulatory procedural program directed at sedimentation control. Both have traditionally stressed voluntary compliance including informative educational programs and incentive systems. To develop a sedimentation program which has enforceable provisions would require monitoring, surveillance, enforcement. and other regulatory practices requiring new authorization and additional personnel.

For urban areas the institutional arrangement problem is not as severe, and there is some question whether a sedimentation control program would encounter the same difficulties in urban areas as it would in rural ones. However, the State is awaiting the results of the Washington County project in the hopes that the experience gained from the project can be used to develop sedimentation practices, programs, and institutional arrangements at the local level.

In 1972 Pennsylvania passed a law requiring all earth-moving activities to have erosion and sedimentation control plans approved by the State except where the plans have been developed by the U.S. Soil Conservation Service. This is similar in many respects to the Michigan law. Agricultural operations are excluded until 1977 in Pennsylvania, and 1979 in Michigan.

In summary, the States within the Great Lakes Basin are in the following stages of erosion and sedimentation control; laws have been enacted in Michigan, Ohio, and Pennsylvania; laws have been drafted and introduced in Illinois, Minnesota, and New York. No legislative action has occurred at the State level in Indiana and Wisconsin. However, in the five States without an established State law, general water quality legislation can be applied to curb land use activities that generate excessive sediment.

TABLE 13 Description of State Activity--Erosion and Sedimentation

	Ill.	Ind.	Mich.*	Minn.	N.Y.	Ohio	Pa.*	Wis.
a policy towards sedimentation control from non-point sources			●				●	
standards for agricultural and urban activities to decrease their generation of sediments			●				●	
exemptions from sediment controls			●					
requirements for planning for sediment control in construction activities			●				●	
a system of incentives for improving sediment control in urban and rural areas								
enforcement provisions to force compliance with State statutes for sediment control							●	
a Statewide sediment control plan and program			●				●	
specified management and control of sediments to a specific State agency(s)			●				●	

● currently operating

* only Michigan and Pennsylvania responded to questionnaire

TABLE 14 Evaluation of State Activity--Erosion and Sedimentation

	Ill.*	Ind.	Mich.	Minn.*	N.Y.	Ohio	Pa.	Wis.
magnitude of problem								
serious			●				●	
moderate		●			●	●		●
low								
not detectable								
priority given to problem								
above average			●				●	
average		●				●		●
low					●			
very low/non-existent								
current State activity								
legal statutes			●				●	
administrative rules							●	
public policy formation			●					
incentive programs		●						●
no action					●	●		
likely future State activities								
legal statutes						●		●
administrative rules			●					
public policy formation								
incentive programs								
no action		●			●		●	

* no information available

TABLE 17 Summary of Statutory Regulation--Erosion and Sedimentation

	Ill.	Ind.	Mich.	Minn.	N.Y.	Ohio	Pa.	Wis.
Does the State have a specific statute to control erosion and sedimentation?	yes		yes	yes			yes	
Are any persons or uses exempted from operation of the statute?							yes	
Is there a fine for violation of the Statute?							yes	
Does the State have a streambank stabilization program?			yes, a minor one				yes	
Does the State have legislation to enable local groups of property owners to organize special purpose districts to effect soil conservation practices?	yes	yes	yes	yes	yes	yes, county-wide groups only	yes	yes
Does State law provide for the establishment of Soil Conservation Districts for sediment and erosion control?	yes	yes	yes	yes	yes	yes	yes	yes
If so, do the Soil Conservation Districts have								
taxation power?						yes		
condemnation power?	yes					yes	yes	yes
land purchase power?	yes		yes			yes	yes	yes
Is pipeline and road construction regulated to prevent sediment pollution?	yes		yes	yes	yes		yes	
Do local units of government have the authority to control sedimentation?	yes	yes	yes	yes	yes	yes	yes	yes
Does the State conduct sediment and erosion studies related to land use management practices?			yes			yes	yes	yes
Have sediment and erosion control programs received high priority at State or local levels in the past?	yes	yes				yes	yes	yes
Does State policy favor land management over construction of protective works for sediment and erosion control?	yes	yes	sometimes	yes		yes	sometimes	yes
Do the State's water quality standards make provisions for sediment and erosion criteria?			yes	yes	yes, but not for erosion	yes	yes	yes
Is there a legislated State policy regarding sediment and erosion prevention?	yes	yes		yes	yes, only beach erosion	no	yes	yes

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3.7.7 Intensive Animal Feedlots and Animal Waste

In recent years there has been a move towards adopting concentrated animal feedlots practices for various types of animal production operations in the Great Lakes Basin. These operations have resulted in significant loads of animal wastes in concentrated form which can present serious non-point runoff of biological material.

It has been shown that intensive animal feedlots, depending on the types of animal housed in these operations, can generate significant loads of waste materials. These include BOD, COD, nitrogen, and combinations of nitrates, potassium, and phosphorus, as well as other specific types of residual matter.

Although the EPA has established guidelines applicable to feedlots within certain sizes of operations under the NPDES Program, most States have not provided any regulations or control procedures to limit or handle the resulting animal wastes.

The major activity at the State level in this regard has been in the states of Minnesota, Illinois, and Indiana, where intensive animal feedlots have, in the past, posed serious problems to water quality. In most situations intensive animal feedlots are not located near high density urban areas, and their effect on surface waters is not as great as other land-use activities. However, in cases where intensive animal feedlots cause serious water quality degradation and are brought to the attention of state officials, procedures exist to control the release of these wastes.

The States can regulate intensive animal feedlots through their general water quality statutes and regulations preventing water quality deterioration on the part of land-use activities. In this manner intensive animal feedlots can be handled on a case-by-case basis after water quality degradation has occurred. The procedures generally require hearings, and as a last resort, court proceedings for abatement procedures. This was the case in Indiana up until recent times. Controls were not applied until 1971 where certain intensive animal feedlots were contributing sizable loads of nutrients and animal wastes to streams which resulted in extensive fish kills. In 1971 a law was passed regulating confined animal feedlots, depending on the size of the operations and the seriousness of the problems they were causing. This was approved by the Stream Pollution Control Board and passed as a legislative statute regulating intensive animal feedlots. The control procedure specifically designated that no liquid and solid discharges from animal feedlots would be allowed. This holds true also during peak storm runoff periods. All permits for confined animal feedlots must be approved by the Stream Pollution Control Board, and the Board lists various characteristics subject to approval:

(1) location and physical characteristics of the site

(2) soil characteristics

(3) construction requirements for storage of dry wastes, such as roofing, watering systems, manure stock piling areas, and liquid disposal systems

Guidelines for handling concentrated feeding operations, which conform with the State statutes, were formulated by Purdue University and widely circulated to the farmers in the State. On the local level the farmers were assisted in applying these guidelines by the Agricultural Stabilization and Conservation Service REAP Program, which helped develop operational plans for concentrated animal areas. A specific requirement in the statute was that all wastes must be land applied. No allowance is made for discharges to surface waters during high flow periods. Because of this requirement, the wastes must be lagooned for substantial periods of time in order to derive a regulated flow to land application areas. Regulating flows prevents the land from clogging, as well as preventing strains on the soil's capacity to hold nitrogen.

When approving permits, the Indiana Stream Pollution Control Board takes particular interest in the type of lagooning to be constructed and in the land area waste application system. Its main concern is that sufficient lagooning capacity is made available for storage of wastes during periods when land application is not feasible, such as in winter months. It does not, however, require a soil analysis, except where the soils are a critical aspect in the feasibility of the system. Although slope requirements are not specified, the Board usually takes into account soil slope requirements where they form a significant grade.

No monitoring of soil capability to assimilate animal wastes takes place, although it is recognized that the soil has an absorption capacity over a period of time. Well-designed, engineered, and operated intensive animal feedlots should limit the effects on surface water quality. The program's major limit is the problem of lagoon failures, which in two cases caused extensive fish kills when poultry waste lagoon dikes broke. In both cases, recovery of damages to wildlife was pursued and gained by the Department of Natural Resources.

Although buffer zones to lagoons are required, they are basically for abatement of nuisance items, such as odor near adjacent residential land-use areas where buffer zones of 152 to 305 meters (500 to 1000 feet) may be required.

The Indiana program is an important step since no wastes will be leached from intensive animal feedlots but will be stored and subsequently land disposed. Backing up this program are feedlot operation guidelines developed by Purdue University with field assistance by the U.S. Soil Conservation Service. Thus, the program mixes State regulations by the Stream Pollution Control Board with the Education Extension Services provided by the State University, with the assistance of the U.S. Soil Conservation Service.

At the present time no other State besides Indiana seems to have as extensive a measure of control over intensive animal feedlots wastes. The Illinois Pollution Control Board has proposed regulations governing the construction location and operation of feedlots and animal waste treatment. However, they are still in the hearing stages. Other States are relying on generalized pollution control regulations to handle waste loads resulting from confined animal feedlots.

In New York and Wisconsin codes of practice or "good practice guidelines" for the disposal of agricultural wastes have been developed and prepared. These are similar to the ones developed by Purdue University. The New York guidelines deal with site selection, handling and storage of wastes, disposal of wastes, and some specific construction criteria.

Minnesota has a set of specific pollution control regulations which deal with livestock and feedlot wastes, but these were developed in reference to solid waste control.

TABLE 18 Description of State Activity--Animal Feedlots and Animal Wastes

	Ill.*	Ind.	Mich.	Minn.*	N.Y.	Ohio	Pa.*	Wis.*
a policy on controlling animal wastes impacts on water quality		•	•		•	•		
regulations for controlling								
runoff		•						
construction of feedlots		•				•		
operation of feedlots		•	•		•	•		
incentives for animal wastes treatment and/or reuse								
a monitoring program for evaluating impact of animal wastes on water quality		•						
enforcement provisions controlling animal feed-lot impacts on water quality		•						

• currently operating

* Illinois, Minnesota, Pennsylvania, and Wisconsin did not respond to questionnaire

TABLE 19 Evaluation of State Activity--Animal Feedlots and Animal Wastes

	Ill.*	Ind.	Mich.	Minn.*	N.Y.	Ohio	Pa.	Wis.
magnitude of problem								
serious		•						
moderate			•					
low					•	•	•	•
not detectable					•			
priority given to problem								
above average		•						
average								
low			•		•	•	•	•
very low/non-existent								
current State activity								
legal statutes		•						
administrative rules		•			•	•		•
public policy formation		•						
incentive programs		•	•					•
no action							•	
likely future State activities								
legal statutes		•						
administrative rules		•						•
public policy formation		•	•					•
incentive programs		•						•
no action					•	•	•	

*no information available

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TABLE 20 Description of Statutory Regulation--Animal Feedlots and Animal Wastes

	Ill.	Ind.	Mich.	Minn.	N.Y.	Ohio	Pa.	Wis.
specific regulations adopted		●		●				
proposed	●							
no action			●		●		●	●
adequate water quality regulations			●		●	●	●	
state involvement concerns discharge abatement		●		●	●	●		
storage		●		●	●			
manure disposal		●		●	●			●
monitoring soil capacity								
surface waters			●					
ground waters								●
discharge abatement requirements total		●		●				
partial				●	●			●
none			●		●			
disposal regulations land only		●		●				
land and/or water				●	●			●
primary waste treatment		●					●	
adopted guidelines site selection		●			●			●
storage		●			●			●
disposal		●			●			●
agency involvement								

3.7.8 Forestry

Forestry activities were specifically pointed out in the Federal Water Pollution Control Act Amendments of 1972 in Section 304-E as an important non-point pollution source. The types of pollutants generated in forestry activities include the following:

(1) Sedimentation. Sedimentation and erosion are affected by roads and skid trails used in logging operations. These trails provide access for equipment and are used for transporting logs out of forests. Burning contributes to sedimentation loads when it is used to clear out forest undergrowth and remove ground level vegetation. Natural landslides also leave soil exposed to erosion and sedimentation. Streambank erosion can be significant especially where the banks are not reinforced or anchored by any structural measure. Logging operations can increase the rate of streambank erosion when the operation is near a streambank or locates its road sites adjacent to streambanks.

(2) Nutrient Elements. The two major forms of nutrients are nitrogen and phosphorus generated from natural debris, artificial fertilization techniques, and fire retardents which use nitrogen and phosphorus. Nutrient loads from forestland areas can be carried off by surface runoff to streams and rivers, eventually draining into the Great Lakes. Waste excretions of forest animals also contribute to the nutrient load.

(3) Biochemical Toxins. Pesticides form the major toxic materials present in forestry which can degrade water quality and affect wildlife in the area as well as possibly affecting downstream water quality.

(4) Thermal Pollution. Thermal pollution is derived from the removal of shade areas over streambanks, either through silvicultural activities, or from burning operations. By removing shading vegetation, stream water temperatures can increase and adversely affect certain forms of aquatic plants and animal life.

The management and control of forestry activities to prevent adverse effects on water quality are presently constrained by several factors. First of all, ownership of the land is a problem. In national forest areas Federal laws apply to the operation of silvicultural and other activities. All new operations must supply environmental impact statements and meet established Federal guidelines which deal with sedimentation, nutrient, and pesticide loads.

For State lands, State and/or Federal regulations are usually in force. Few regulations exist which control activities relevant to water quality on private forest lands. Only State sedimentation and pesticide regulations have any control over land-use activities in private forests (3).

Silvicultural activities fall within the purview of States' plans for sedimentation control as they are now being formulated. Specifically, these regulations will deal with forest road constructions, skid trails and other transportation activities, plus lumbering procedures involved with such aspects as clear cutting (22-A10). It is reasonable to expect that primary consideration will be given to lumbering operations where the rate of sedimentation is normally greater than for either recreational or undeveloped forest areas.

Most States do not have regulations concerning nutrient control. Aerial spraying of fertilizers on reforested areas could result in significant nutrient loads being transmitted directly to surface waters. No State has formulated actions limiting or regulating height of aerial application, location, or other forms of nutrient control and no State regulatory statutes exist concerning nutrients generated from forest debris and wildlife wastes, nor are they foreseen in the immediate future. Nutrients generated from burning activities in silvicultural operations have not received State level attention on regulating methods of burnings or location and time of burnings to reduce the release of nutrients into the atmosphere (26).

Pesticide applications on Federal and State lands are regulated by a variety of guidelines and procedures, either under Federal statutes concerned with Federal lands, or State lands that are financed through Federal funds, or through State guidelines and regulations applied to State lands. However, the application of pesticide regulations to private lands is currently limited and not significant (47).

The major form of regulating the private use of pesticides is controlling the sale of certain toxic materials to private users and regulating the labeling of containers so that appropriate directions and possible adverse affects from misuse of pesticides is plainly labeled and noted for private users. Pesticides, such as aldrin, are particularly toxic to wildlife. When aerially sprayed, it can directly affect surface water and wildlife. Recent research has shown that sedimentation is a major carrier of pesticide residuals into aquatic environments. Therefore, strong enforcement of erosion and sedimentation controls may reduce the impact of pesticide residuals on water quality. However, this would not substantially reduce the outfall of pesticides from the atmosphere due to aerial spray practices near surface waters.

No regulations or statutes control thermal pollution of surface waters in forest areas. In the basin area presently such regulations would have to deal with the alteration of shade covering near streambanks. This is an area which has not experienced management and control up to this point in time, but may in the future when studies treating the effects of temperature changes in stream waters on aquatic environments are further documented.

In summary, forestry activities are viewed as not generating significant pollution loads on surface water qualities and not noticably affecting ground-water quality. Forestry activities probably will continue to receive relatively low priority at the State level for management and control procedures in reducing non-point source loading to water areas (24). One reason for this is the lack of adequate information on forestry on which to base regulations. Only recently has there been an attempt to estimate the loadings of nutrients, sediments, and pesticides from forestry activities. Until a determination can be made on the effect of various land-use activities in forest areas on water quality, State management and

and control will probably be limited to certain major operations such as lumber removal. The A-10 Report pointed out that when: "Adequate information becomes available, it may be necessary to implement harvesting, grazing, recreation, and prescribed burning techniques." (22-A10).

Another reason for the lack of procedures aimed at forestry operations is the relatively small quantity of pollutants generated on forest lands in relationship to other land-use activities. Because of limited funds and personnel to monitor and enforce regulations, the setting of priorities will probably give forestry activities limited attention.

A problem in any type of control legislation will be in monitoring and enforcing State guidelines and programs on privately owned forest areas. Presently the majority of forest land is privately owned in scattered locations. The ability to monitor forest operations under these conditions is difficult unless substantial increases in manpower are generated for this function. This is not a realistic possibility at the present time.

Conformance to land-use management practices to reduce non-point source loadings from forests will rely on voluntary cooperation under present conditions. This means that efforts at educational extension activities by State universities or by other services such as the Soil Conservation Service and Soil Conservation Districts, or through the U.S. Forest Service and State forest service departments will be necessary.

Incentives to utilize land use management programs should also be generated. These include subsidizing erosion control projects on the land or providing tax incentives to undertake operations which would reduce the non-point source loading capacities of forests on receiving water areas.

TABLE 21 Description of State Activity--Forestry

	Ill.*	Ind.	Mich.	Minn.*	N.Y.	Ohio	Penn.*	Wis.
regulates the use of herbicides and pesticides		●	●					
regulates their method of application								●
disposal			●		●			●
regulates burning activities			●		●	●		●
controls harvesting operations								
provides incentives for sediment and erosion control								
monitors silvicultural operations impacts on water quality								
applies State policies equally to public and private forests								
requires water quality impact statements for silvicultural actions								
provides enforcement provisions to implement controls								

● current activity

* Illinois, Minnesota, and Pennsylvania did not respond to questionnaire

TABLE 22 Evaluation of State Activity--Forestry

	Ill.*	Ind.	Mich.	Minn.*	N.Y.	Ohio	Pa.	Wis.
magnitude of problem serious								
moderate								
low								●
not detectable		●	●		●	●	●	
priority given to problem above average								
average								
low								
very low/non-existent		●	●		●	●	●	●
current State activity legal statutes								
administrative rules								
public policy formation								
incentive programs								
no action		●	●		●	●	●	●
likely future State activities legal statutes								
administrative rules								
public policy formation								
incentive programs								
no action		●	●		●	●	●	

*no information available

3.7.9 Effects of Recreational Land Use on Water Quality in the Great Lakes Basin

The major impetus behind recreational land-use regulations is the dramatic increase in recreational activities during the past several decades. User levels have increased proportionately beyond recreational land expansion, causing the intensity of land use to increase dramatically over time. This adds a substantial burden to these areas to sustain recreational activities without significant degradation of land and adjacent waters. Recreational activities can be approached from at least three major points. General water quality regulations and standards can apply to parks, cottage and second home subdivision, and other recreational land uses to abate point source pollution. In instances where the pollution is significant, measures can be required to limit or prevent non-point source pollution. Existing laws and standards regulating sedimentation, applications of pesticides and herbicides, and animal wastes provide another control. Sedimentation control ordinances in Michigan and Pennsylvania deal with erosion and sedimentation resulting from construction of ski resorts, recreational beaches, parks, and other recreational areas. However, a major drawback in this approach is the lack of adequate control over daily individual activities. Erosion and sedimentation control ordinances do not specifically cover individual recreational users, such as families on outings or persons with all-terrain vehicles traversing undeveloped area.

Because of this, a third possible method to control the effects of recreational land uses on water quality is through limiting personal activities to designated recreational areas. These statutes and provisions may include the use of off-road recreational vehicles, motorcycles in non-paved areas, skiing and snowmobiling, and other activities (22-A11). Because most recreational activities are of recent origin, many States have yet to formulate personal behavior standards on these lands.

State and national parks have begun to regulate recreational vehicle flows through parks and the numbers of visitors allowed into camping areas in order to control any adverse effects on animal and plant life. The effects of recreational land-use activities on natural preserves, however, is expected to increase in the forthcoming years.

The difficulties lie not with regulation formulation, but in establishing control procedures to insure observance of the regulations (20). Parks or other State lands can be partially managed by regulating visitor flows through recreational areas. However, for many recreational areas not included in State or Federal park systems, the ability to control traffic is limited to on-site monitoring and inspection or enforcement of complaints. Thus, in instances where off-road vehicles traverse lands subject to erosion and sedimentation, it is currently difficult to provide sufficient monitoring to insure compliance with evolving State programs addressed to this activity.

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Unlike agricultural extension services which assist in generating voluntary compliance to land-use practices for the reduction of sedimentation, there is no currently established program to foster specific land-use management practices for individuals in their pursuit of recreational sports. It is difficult at present to foresee widespread programs to generate voluntary compliance to recreational behaviors which insure against adverse effects on water quality.

One alternative method may be the banning of certain recreational activities such as off-road vehicle use in undesignated land areas. However, this is difficult to enforce in many undeveloped and isolated areas without generating undue costs in terms of manpower.

The Upper Great Lakes Regional Commission is developing model legislation covering registration, insurance, highway operation, violation handling, required equipment, local ordinances, structures of general enforcement provisions, and educational and training programs for off-road vehicles.

Minnesota, Michigan, and New York prohibit snowmobile operation in areas where damages to vegetation and terrain may occur. However, the development of nonmotorized zones to protect wildlife and other ecological systems, although being proposed in many areas, has not been used extensively.

New York and Minnesota restrict snowmobile use in forest preserves to designated trails and prohibit their cross-country travel. Michigan is currently studying environmental damage resulting from recreational activities as well as behavior responses to regulations. Most States require off-road recreational vehicle registration. For most of the other recreational activities, few State-level regulations currently exist.

Most of the Basin States do not consider recreational activities as a significant factor affecting land-use water quality relationships when compared to other land-use activities such as residential, commercial, and extractive operations. However, shoreline management programs may offer potential leverage in controlling water degradation resulting from recreational use of shorelines (2).

In Michigan local shoreline zoning is required in designated areas. If no action is taken at the local level to zone shorelands for protection of designated high risk erosion areas within three years of April 1974, the State Department of Natural Resources and the Michigan Water Resources Commission can establish their own regulations to prevent unwise use of such properties. The main aim of the program is to reduce the financial losses which occur in such areas from structural collapse of buildings in erosion prone areas. However, although zoning promises to afford a measure of control over shoreline erosion and subsequent degradation of near shorewaters, it will affect cottage and second home development, shoreline recreational uses--including off-road vehicles--sporting events, and other activities in high risk erosion areas (13). This probably will be a trend throughout the Basin States in the forthcoming years as demand for recreational space along the shoreline areas of the States increases. Either State level or local level zoning and use regulations will need to be adopted in order to preserve coastal areas from significant degradation and to prevent siltation of the Great Lakes.

TABLE 23 Evaluation of State Activity--Recreational Land Use

	Ill.*	Ind.	Mich.	Minn.*	N.Y.	Ohio	Pa.	Wis.
magnitude of problem								
serious								
moderate								
low			●		●			●
not detectable		●				●	●	
priority given to problem								
above average								
average								
low							●	
very low/non-existent		●	●		●	●		●
current State activity								
legal statutes								
administrative rules					●			
public policy formation								
incentive programs								
no action		●	●			●	●	●
likely future State activities								
legal statutes							●	
administrative rules							●	
public policy formation								
incentive programs								
no action		●	●		●	●		●

*no information available

563<

3.7.10 Undeveloped Land

Undeveloped areas in the Great Lakes includes forests, wetlands, uplands, streambanks, and shorelands. They account for a major land-use category in the Basin. Forest covers 46 percent of the Basin while 9 percent of the remaining lands include wetlands and uplands (22-A12). The management and control of undeveloped land has not incorporated controlling pollutants generated from these lands which may affect water quality. This is primarily due to the limited available knowledge concerning aspects of "natural pollution." Thus, no land or water treatment controls have been developed among the States to deal with this form of non-point source water degradation.

The major forms of natural pollution include sedimentation, due to either natural runoff or streambank and lakeshore erosion, biological matter derived mainly from trees, tannic acid from decaying materials, and suspended materials in the atmosphere which may fall out either on land or directly into surface waters. Approximately 10 to 15 percent of the total suspended materials in the Lakes come from undeveloped areas (22-A12).

Although there are various State regulations and controls dealing with undeveloped areas, particularly State lands, no regulations exist to control the effects of "natural pollution" on water quality, excluding dredging operations which remove sediments from natural erosion and sediment runoff of surrounding lands. Although undeveloped land generates significant amounts of sediments and biological matter, the States currently do not view undeveloped areas as priority areas for implementing State regulatory practices.

While these areas are considered to be insignificant in terms of their non-point source loading of pollutants to the Great Lakes, this does not mean that management strategies could not be implemented on undeveloped lands. It would be possible to control sedimentation from shorelines, streambanks, and upland areas through drainage techniques and conservation practices which are currently applied to agricultural lands (22-A12). Such practices would reduce erosion runoff, provide impoundment of surface runoff waters, and allow for settling basins to filter out suspended particles and solids before they reach surface-water areas. Removal of sediments and biological matter in upstream areas is possible to prevent the drift of these materials into downstream areas.

Because there are no excessive loads generating from undeveloped lands, the States are not likely to apply management and control practices to these areas because the necessary funding and manpower would detract from other programs. Because other forms of land-use activities have been documented as significant point and non-point sources of residuals, State resources are being allocated to these priority areas first. Also, the majority of undeveloped lands are privately owned, creating added difficulties in passing legislation authorizing State regulation of private undeveloped lands.

TABLE 24 Evaluation of State Activity--Undeveloped Land

	Ill.	Ind.	Mich.	Minn.	N.Y.	Ohio	Pa.	Wis.
magnitude of problem serious								
moderate								
low								
not detectable	●	●	●	●	●	●	●	●
priority given to problem above average								
average								
low								
very low/non-existent	●	●	●		●	●	●	●
current State activity legal statutes								
administrative rules								
public policy formation								
incentive programs								
no action	●	●	●	●	●	●	●	●
likely future State activities legal statutes							●	
administrative rules							●	
public policy formation								
incentive programs								
no action	●	●	●	●	●	●	●	●

3.7.11 Liquid Waste Disposal

Wastewater disposal on land, although an old phenomenon, has recently received attention as an alternative method for handling municipal sewage. Within the Great Lakes Basin several municipalities are disposing wastewaters on land. Most of these municipalities have a population of under 10,000, and only one--Muskegon, Michigan--has a population of more than 40,000 (22-A13). Except for two systems, all handle less than a million gallons of daily sewage. Another source of wastewater comes from industrial plant land applications. These are quite numerous and include crude processing textile and related biological material, food processing, and canning companies.

A recent survey conducted by the American Public Works Association Research Foundation determined that most State agencies have no set policies on the land application of wastewater and its effect on the environment, even though they come under the National Pollution Discharge Elimination System purview (47). The States also do not set specific construction requirements for these lands. Application methods, monitoring, and inspection procedures are infrequent on the part of State officials. While all States in the Basin have standards and criteria for regulating liquid waste disposal operations, the onlv State with specific regulations is Pennsylvania. However, there are management intervention points which can be used to control land application of industrial and municipal wastewaters. These are as follows:

(1) The regulation of the location of land application sites would depend on soil type, permeability of the soil, underlying aquifers, and ground and surface waters to reduce the effect of these waste loads on water quality.

(2) The type of waste being applied to land should be determined as to its organic and inorganic chemical and biological content, toxic levels, and other parameters which would influence its effect on water quality.

(3) The amount of wastes which can be applied can be controlled by recognizing the soil's capacity to assimilate the wastes over time. This also helps regulate the buildup of nutrients in the soils such as nitrogen and phosphorus.

(4) A fourth requirement is the sanitation and chlorination of wastewaters, either by secondary treatment techniques, chlorination, or a combination of both. This is presently being done in Pennsylvania.

(5) A fifth strategy can utilize buffer zones from other land-use practices to insure that applications of wastewater, especially through aerial spray irrigation methods, have sufficient air buffer zones to prevent the dispersal of aerosol particles into adjacent residential and commercial areas.

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(6) Settling basins and drainage basins can be required where land configuration causes wastewaters to gather at certain points. Settling basins can prevent runoff of sediments during heavy stormwater runoff.

The survey of State water pollution control agencies by the American Public Works Association highlights the lack of regulations dealing with land application systems. From the questionnaires returned by 27 of the states answering, only 7, including Minnesota, revealed any statutes, regulations, criteria, or standards relating to land treatment. The following are existing regulations among the seven States dealing with liquid waste disposal:

(1) effluent pretreatment requirements

(2) distinctions between sewage and industrial waste

(3) control of the quality of effluent applied to land

(4) required storage of applied effluent

(5) standby acreage

(6) buffer zones

(7) area protection

(8) safety and safeguard requirements

(9) recognized seasonal variations

(10) design guidelines

The most common practice was the use of effluent pretreatment techniques, and the second most common requirement was design guidelines. Most States have regulations or legislation dealing with land treatment methods of municipal sewage disposal, but they do not necessarily cover industrial waste disposal.

In the Temple University survey in 1972, New York and Wisconsin had administrative regulations and statutes for municipal application of wastewaters to the land (46). Illinois and Michigan were also included. In the case of Michigan land treatment is permitted but with restrictions. The Temple University study did not present sufficient data for Indiana, Minnesota, Ohio, and Pennsylvania.

The main arguments against land application of municipal wastes are the potential public health risks, water pollution, and social effect, especially since substantial tracts of land are required for these operations.

The American Public Works Association Research Foundation and the Temple University studies both revealed that among health and water pollution control agencies of the States surveyed, very few of them have specific statutes or regulations relating to land treatment of liquid wastes. However, most of them had some informal guidelines, while others operate on a case-by-case basis. It was determined in the studies that the statutes and regulations in New York and Wisconsin are favorably orientated towards land treatment techniques.

The Illinois Environmental Protection Agency has set standards for treatment which set forth detailed guidelines for applying for a permit to operate a land disposal facility. The guidelines include requirements for location, topography, soils, geology, hydrology, agricultural practices, and adjacent land uses. Specific regulations concern soil slopes, agricultural practices, hydrology, treatment of effluent before the disposal, piping of the effluent to the sprinklers, location of sprinklers, surface runoff, and fencing and warning signs. They also require secondary treatment before application. Chlorination is required for spray irrigation practices.

In Indiana no regulations or standards have been formulated for land application of wastewaters. The State operates on a case-by-case basis. So far there is one municipality and sixteen industrial land disposal sites. The basic requirements for all these locations is that a permit must be obtained and monthly reports submitted concerning the flow and composition of wastes to the State's Stream Pollution Control Board.

Michigan's requirements include buffer zone designs, a drainage system beneath the land application site entailing a tile system, and a buffer zone with a minimum distance of 244 meters (800 feet) between the waste application site and adjacent land area. An elaborate set of guidelines exists for monitoring ground water at the disposal site.

Minnesota has developed design criteria. Wastewaters must be disinfected, using chlorination and secondary treatment. Requirements also prescribe the size of land and dosage rates of wastewater to be applied. The regulations require a storage area able to hold a minimum of 210 days of wastewater. This means that a holding pond or lagoon system must be constructed adjacent to the land application site. Buffer zones, fences, warning signs, specific distances to water supply sources, homes and parks, and underground drains and monitoring wells are also required.

New York does not have any specific standards or regulations applying to land treatment techniques. The State operates on a case-by-case basis, giving consideration to field topography and soil characteristics, including infiltration and percolation rates, soil, ground-water and aquifers characteristics, climatic conditions, and crops to be utilized. Each project is reviewed with specific reference to water balances. The State does not approve systems that allow runoff to surface waters. Because this is a land treatment system, it must operate with a closed system with no drainage to surface waters and minimal drainage to ground-water areas.

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In this context land treatment of wastewater is not used as a means to recharge aquifers. Spray irrigation is only permitted during growing seasons. However, no restrictions are placed on the types of wastewater which are to be sprayed. This means that pH can range considerably, although it is desirable within the range of 6 to 8.5. High concentrations of sodium are not encouraged. Yet, control of them is questionable. Finally, the State is attempting to discourage the discharge of wastes which are high in non-biodegradable substances, such as phosphorus.

For Pennsylvania the Department of Environmental Resources must approve and issue permits for the operation of land application techniques. No particular degree or method of wastewater treatment is specified or prohibited under the statutes. However, the Pennsylvania Sanitation Water Board does require that all biodegradable and non-biodegradable waste receive secondary treatment. There is a clause that waste can be deposited into a stream polluted by coal mine discharges, but it must undergo primary treatment. All other discharges require secondary treatment. There are no specific standards or permit systems dealing with land disposal of wastewater. A manual of guidelines has been prepared and includes standards for site selection, systems operation, and installation of equipment. The maintenance of a storage area is recommended to provide a specific dosage rate throughout the season. The ground water must be at least ten inches below the surface. Monitoring wells are required at all sites. The Pennsylvania guidelines do not specify the types of crops which can be grown at these land treatment sites.

Wisconsin does not have any standards or statutes dealing with land treatment techniques. Land applications usually come under sewage regulations, and these regulations do include land application techniques as part of their coverage. The State operates on a case-by-case basis, concentrating on the designs and specification of the particular wastewater treatment system. Evaluation of the plans include location, geology, hydrology, soils, areas for future expansion, and adjacent land uses. Raw sewage cannot be applied to land.

The major difficulty in formulating specific State regulatory practices concerning land application techniques of liquid wastes is the relative lack of knowledge about the effects of applying municipal liquid wastes on land over a period of time (22-A13). This includes such things as the buildup in nutrients such as nitrogen and phosphorus over a period of years (50).

Industrial wastes are usually not considered a significant problem because the wastes are usually sanitized before disposal. This is not true of municipal wastes which contain potential public health hazards if improperly disposed. Since land application techniques depend heavily on soil characteristics for providing filtration and cleansing actions, guidelines and regulations must take into account the disparity in soil properties from one place to another within a State. Thus, instead of utilizing guidelines and practices, States tend to be specifying which practices are acceptable in land-use application techniques.

Land application systems, especially with regard to municipal waste applications, are currently restricted to rural or semi-urban areas generating limited amounts of effluent wastes. Application of this practice to high density urban areas is unfeasible due to the lack of sufficient land areas, conflicting land uses, and the amounts of waste.

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TABLE 25 Evaluation of State Activity--Liquid Waste Disposal: Municipal Areas

	Ill.*	Ind.	Mich.	Minn.*	N.Y.	Ohio	Pa.	Wis.
magnitude of problem								
serious								
moderate								
low							●	
not detectable		●	●		●	●		●
priority given to problem								
above average								
average		●	●		●	●	●	
low								●
very low/non-existent								
current State activity								
legal statutes			●		●	●	●	●
administrative rules		●	●		●	●	●	●
public policy formation		●	●				●	
incentive programs								
no action								
likely future State activities								
legal statutes								
administrative rules								
public policy formation								
incentive programs								
no action		●	●		●	●	●	●

*no information available

TABLE 26 Evaluation of State Activity--Liquid Waste Disposal: Industrial Areas

	Ill.*	Ind.	Mich.	Minn.*	N.Y.	Ohio	Pa.	Wis.
magnitude of problem								
serious								
moderate		●	●				●	
low					●	●		●
not detectable								
priority given to problem								
above average								
average		●	●		●		●	
low						●		●
very low/non-existent								
current State activity								
legal statutes		●	●		●	●	●	●
administrative rules		●	●		●	●	●	●
public policy formation								
incentive programs								
no action								
likely future State activities								
legal statutes								
administrative rules								
public policy formation								
incentive programs								
no action		●	●		●	●	●	●

*no information available

3.7.12 Solid Waste Disposal

Among the various States in the Basin, solid waste disposal operations have generally been considered a local responsibility. Recently, however, the trend has shifted towards State level permit systems for constructing and operating landfill sites. In addition, all the States have fostered the use of landfilling methods instead of open dump operations with State monitoring of these operations to insure compliance with environmental guidelines. All the States, in issuing permits for constructing and operating sanitary landfills, require review of probable effects of leachates and certain chemical toxins upon ground and surface water areas. Nevertheless, each State differs in the degree to which such regulations are implemented.

In most States, current landfill regulations apply to both public and private disposal operations, although the regulations do not usually affect the physical disposal of materials by individual property owners, such as on farmland and small industrial sites. The variations that exist in the regulations basically revolve around accounting for the differences in topographical features, soil conditions, terrain, and other factors influencing the effect of leachates on ground and surface water quality in nearby areas.

Indiana currently bans all non-landfill sites, such as open burying dumps. Wisconsin has graduated disposal criteria. For areas with less than a population of 2,500, open dump burning is allowed in specific areas provided stringent criteria are met. However, larger towns are required to have a sanitary landfill operation in lieu of other forms of solid waste disposal. New York, however, requires disposal objectives, depending on the physical features of the operation. Impermeable barriers may be required in every State, depending on a case-by-case determination, although complete entrapment of leachates and other materials is an exception at the present time.

One of the difficulties in formulating regulating controlling disposal operations influence on water quality is due to the lack of extensive information on the influence of leachates. A general range of effects can be determined from modeling methods. However, beyond this level, it is difficult to set management strategies beyond general determinations as to site quality and proposed engineering specifications for the landfill operation. In all the States the division which regulates water quality permits also has the authority to approve permits for landfill site applications to insure consideration of water quality standards.

Most of the States do not allow toxic materials, oils, or highly organic materials in the landfill sites. However, New York currently does not have regulations controlling the types of materials which can be applied at landfill sites. This determination is at the discretion of the landfill operator. Thus, highly organic materials or materials such as oils, are not currently regulated on a State-wide basis in New York. New York is planning to pass regulations prohibiting various types of materials at landfill sites without a permit. Indiana, on the other hand, has statutes regulating toxic materials, oils, and highly organic materials which cannot, without proper procedures be disposed of at landfill sites. Almost all the States have regulations prohibiting the disposal municipal waste treatment sludge unless they have a certain percentage of solids content, usually around 70 percent. Almost all the States do not directly monitor landfill sites except in initial permit seeking stages. If problems arise, however, periodic checks are made. Most monitoring procedures are assigned to landfill operators or to local authorities. However, adequate monitoring is difficult because of lack of qualified manpower with knowledge about proper disposal operations.

Almost all the States require that sanitary landfill sites be covered daily except for rural areas in Wisconsin and New York where daily coverage operations may be waived. All the States require licensing of landfills, while some require licensing of the operators as well.

TABLE 27 Description of State Activity--Solid Waste Disposal

	Ill.	Ind.	Mich.	Minn.	N.Y.	Ohio	Pa.	Wis.
controls the runoff from land disposal sites		•	•				•	•
regulates their location in terms of water quality impact	•	•	•	•	•		•	•
establishes a list of standards and regulations to minimize impact on ground/surface waters	•	•	•	•	•		•	•
provides monitoring and enforcement procedures	•	•	•	•	•	•	•	•
develops incentives for compliance with water quality goals								
applies State programs to private land disposal sites	•	•	•	•	•	•	•	•
limits toxic contents of land disposed residuals		•	•			•		•
trains and/or licenses land disposal site operators		•	•		•		•	•
regulates disposal site construction	•	•	•	•	•	•	•	•
protects surface waters from land disposal site drainage	•	•	•	•	•	•	•	•

• current activity

TABLE 28 Evaluation of State Activity--Solid Waste Disposal

	Ill.*	Ind.	Mich.	Minn.*	N.Y.	Ohio	Pa.	Wis.
magnitude of problem								
serious								
moderate							•	
low			•		•	•		•
not detectable		•						
priority given to problem								
above average								
average			•				•	•
low		•			•	•		
very low, non-existent								
current State activity								
legal statutes		•	•		•	•	•	•
administrative rules		•	•		•	•	•	•
public policy formation		•	•		•	•	•	•
incentive programs								
no action								
likely future State activities								
legal statutes								
administrative rules								
public policy formation								
incentive programs								
no action		•	•		•	•	•	•

*no information available

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TABLE 29 Description of Statutory Regulation--Solid Waste Disposal

	Ill.	Ind.	Mich.	Minn.	N.Y.	Ohio	Pa.	Wis.
Are open dumps prohibited?		●	●		●	●	●	●
Are landfills/ dumps licensed by State?	●	●	●	●	●	●	●	●
Are landfills regulated								
to prevent location where ground water contamination could occur?	●	●	●	●	●	●	●	●
to provide impermeable barrier around								
bottom?		●					●	
sides?		●					●	
topsoil?		●	●	●	●	●	●	
to prohibit certain wastes?		●	●	●		●		●
to prevent surface runoff?		●						
Is there monitoring of ground/surface water impacts								
by the State?		●	●		●	●	●	●
by landfill operators?		●	●		●	●	●	●

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3.7.13 Deepwell Disposal

Ohio passed a law regulating industrial waste disposal wells in 1967. In 1969, Michigan passed its controlling regulations. While the remaining six States do not have specific deepwell disposal legislation, New York (1969), Indiana (1969), and Illinois (1970) have passed policy statements. Most of the Basin States have a variety of regulatory procedures which control waste disposal in wells, although most regulations were not formulated expressly for this purpose. For instance, Indiana regulates deepwell disposal operations through Section 10 of Chapter 214, Acts of 1943 of the General Assembly (23).

> All plans and specifications for abatement or correction of any polluted condition shall be approved by the Stream Pollution Control Board. The Stream Pollution Control Board shall advise and consult on request with any persons planning any correction or prevention of any pollution condition of any waters of this State.

A case-by-case method of regulating deepwell disposal operations is common in the eight Basin States. The points considered in deciding issuance of permits can include:

(1) the nature and amounts of waste fluids--estimated average and maximum volumes of fluids to be injected

(2) injection pressures

(3) composition of wastes, including pretreatment characteristics, flow design, and treated fluid composition

(4) the compatibility of wastes to the receiving formation

(5) possible reactions of the wastes with materials either in the constructed well or in the receiving formation

(6) geological aspects, including topography and subsurface geology of the injection area, possible vertical and horizontal barriers to waste flows, and the hydrology in the formation

(7) engineering specifications, including construction of the well, materials used in the casing, safety procedures, and testing procedures concerning the capacity of the well to operate within given engineering specifications

(8) monitoring programs, including procedures to protect underground aquifers and ground waters from injective wastes

To date regulatory efforts have been directed towards insuring proper geological formations for storage to prevent the seepage of wastes into surrounding subsurface stratum. The use of monitoring techniques, however, is increasing as pressure gauges are being installed within the casings to measure buildup of subsurface pressures, and wells are being drilled near the disposal well to check the flow of wastes in the substrata. A major drawback in regulating deepwells has been the lack of trained manpower to insure compliance with regulatory guidelines (22-A16).

Most of the States have not encouraged this form of disposal due to limited knowledge concerning the effects of subsurface waste injections on various geological formations and their consequences on ground water and aquifers. More stringent restrictions on the composition of materials to be injected, the location of underground storage areas, and emergency precautions are likely. In this respect, subsurface injections will be viewed as a method of waste storage rather than a form of final disposal, and requirements concerning the adequacy of storage will probably be increased (36) (38). Currently abandoned wells present potential problems in Michigan and Ohio. The movement of wastes in these abandoned wells cannot be detected without costly monitoring operations. Because of this, abandoned wells are left unchecked until serious problems become apparent.

Capping of abandon wells similarly is not undertaken unless problems arise and are brought to the attention of the regulatory agency. This reflects the limits on manpower and other resources available to continually monitor and provide means to insure protection of ground and aquifer water supplies against subsurface waste disposal operations (48).

Currently neither Wisconsin nor Minnesota has disposal wells. This situation is unlikely to change in view of the general subsurface conditions in both States and their reluctance to encourage well disposal methods. Illinois is now considering all aquifers with less than 5,000 milligrams per liter of dissolved solids as potential fresh water sources and thus unsuitable for any form of waste injection. There are five existing deep disposal wells in the northern part of Ohio. A recent modification of Ohio statutes prohibits the injection of waste materials into the ground, which, along with strict regulation of existing well disposal operations, makes it unlikely that new wells will be drilled. Since there are no known reservoirs of good disposal quality in the basin part of Pennsylvania, it is also unlikely that there will be future deepwell disposal operations in that area. Only three disposal wells were completed in 1965 and 1968, and all are now plugged and abandoned.

The U.S. Geological Survey is studying the hydrology of the Potsdam Formation in cooperation with the New York Geological Survey. Conclusions have not yet been reached about deepwell disposal in this area. However, New York is attempting to discourage deepwell disposal by regulatory practices and make deepwell disposal a last resort. So far, only two disposal wells have been drilled in New York, although no wells are presently in operation.

In the State of Michigan there are 85 known disposal wells. At least eight have been abandoned and several others are not in use. Under Act. No. 315 of the Public Acts of 1969, the State developed guidelines and regulations controlling the operation and location of deepwell injection sites.

A limiting aspect in improving regulatory measures in Michigan over deepwell disposal operations lies in the lack of control of wells whose locations were never recorded and where the need to plug and fill them as well as monitor their flow of waste over a period of time is not currently being assumed by any one person or agency. These wells are generally discovered only when seepage problems arise.

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TABLE 30 Description of State Activity--Deepwell Disposal

	Ill.	Ind.	Mich.	Minn.	N.Y.	Ohio	Pa.	Wis.*
a position concerning deepwell disposal	●	●	●		●	●	●	
standards on deepwell								
operations	●		●		●		●	
construction	●		●		●	●	●	
location	●		●		●	●	●	
enforcement provisions for gaining compliance with State policies and regulations	●	●	●	●	●	●	●	
monitoring procedures to evaluate operations impacts on ground and surface water quality	●	●	●	●	●		●	
limits on the types and amounts of substances which can be deepwell dispersed	●	●	●	●	●		●	
depth regulations								
standards for abandoning disposal wells	●	●	●	●	●		●	

● currently operative

* by administrative order, Wisconsin prohibits deepwell disposal

TABLE 31 Evaluation of State Activity--Deepwell Disposal

	Ill.*	Ind.	Mich.	Minn.	N.Y.	Ohio	Pa.	Wis.
magnitude of problem								
serious			●					
moderate								
low		●			●	●	●	
not detectable								
priority given to problem								
above average			●					
average						●		
low		●			●		●	
very low/non-existent								
current State activity								
legal statutes			●					
administrative rules		●	●		●	●		
public policy formation		●	●			●		
incentive programs								
no action								
likely future State activities								
legal statutes								
administrative rules								
public policy formation								
incentive programs								
no action		●	●		●	●		

*no information available

TABLE 32 Description of Statutory Regulation--Deepwell Disposal

	Ill.	Ind.	Mich.	Minn.	N.Y.	Ohio	Pa.	Wis.
Are subsurface waste injections prohibited?	yes*					yes		yes
Is State policy opposed to deepwell disposal?			yes		yes	yes		yes
Does State have laws relating specifically to disposal wells?			yes			yes		
Does State have policy statement on deepwell disposal?	yes	yes	yes		yes	yes	yes	
Does State have regulations requiring								
registry?	yes	yes	yes		yes	yes	yes	
permits?	yes	yes	yes	yes	yes	yes	yes	
a stratum of disposal?	yes	yes	yes	yes	yes	yes	yes	
supervision in construction?	yes							
rules/regulations to be handled case-by-case?	yes	yes	yes	yes	yes	yes	yes	

*prohibited in northeastern Illinois only

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Section 4

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